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METRRA SIGNATURE - RADAR CROSS SECTION MEASUREMENTS

Final Report/Instruction Manual

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(11) December 1978

77p.

U.S. Army Mobility Equipment Research and Development Command (MERADCOM)

Contract No. DAAK70-77-C-0189

(15)

New

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SUMMARY

This combined Final Report/Instruction Manual describes the METRRA Signature System designed and developed for the U.S. Army Mobility Equipment Research and Development Command (MERADCOM), Ft. Belvoir, Virginia by Cubic Defense Systems Division. San Diego, California.

Data cellection and reduction was performed at Cubic Defense Systems in San Diego, California.

The technical direction and consultation of MERADCOM's contracting officer's representatives, Mr. Bruce Gabriel and Mr. Pete McConnell in solution to technical problems was greatly appreciated.

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San Diego, California

1. INTRODUCTION.

1.1 General.

This Final Technical Report and Instruction Manual describes the METRRA Signature Test Configuration and Data (hereafter designated METRRA), depicts its performance, and provides operating insight into the test setup.

1.2 Definition of METRRA.

The acronym METRRA represents "Metal Re-Radiating Radar". The METRRA signature tests result from a third harmonic system, since the receive frequency is three times that of the transmit frequency.

Of particular significance is METRRA's inherent ability to penetrate foliage. Conventional radar systems provide returns from undesired targets such as trees, water, dense foliage, etc., while the METRRA system does not. The METRRA process is responsive only to man made non linear junctions. Non linear junctions, when radiated by high power RF energy, convert the energy to harmonic frequencies and re-radiate.

1.3 Purpose of the METRRA Signature.

The METRRA Signature program determines non linear/third harmonic back-scattered radar cross section characteristics of various classes of small targets.

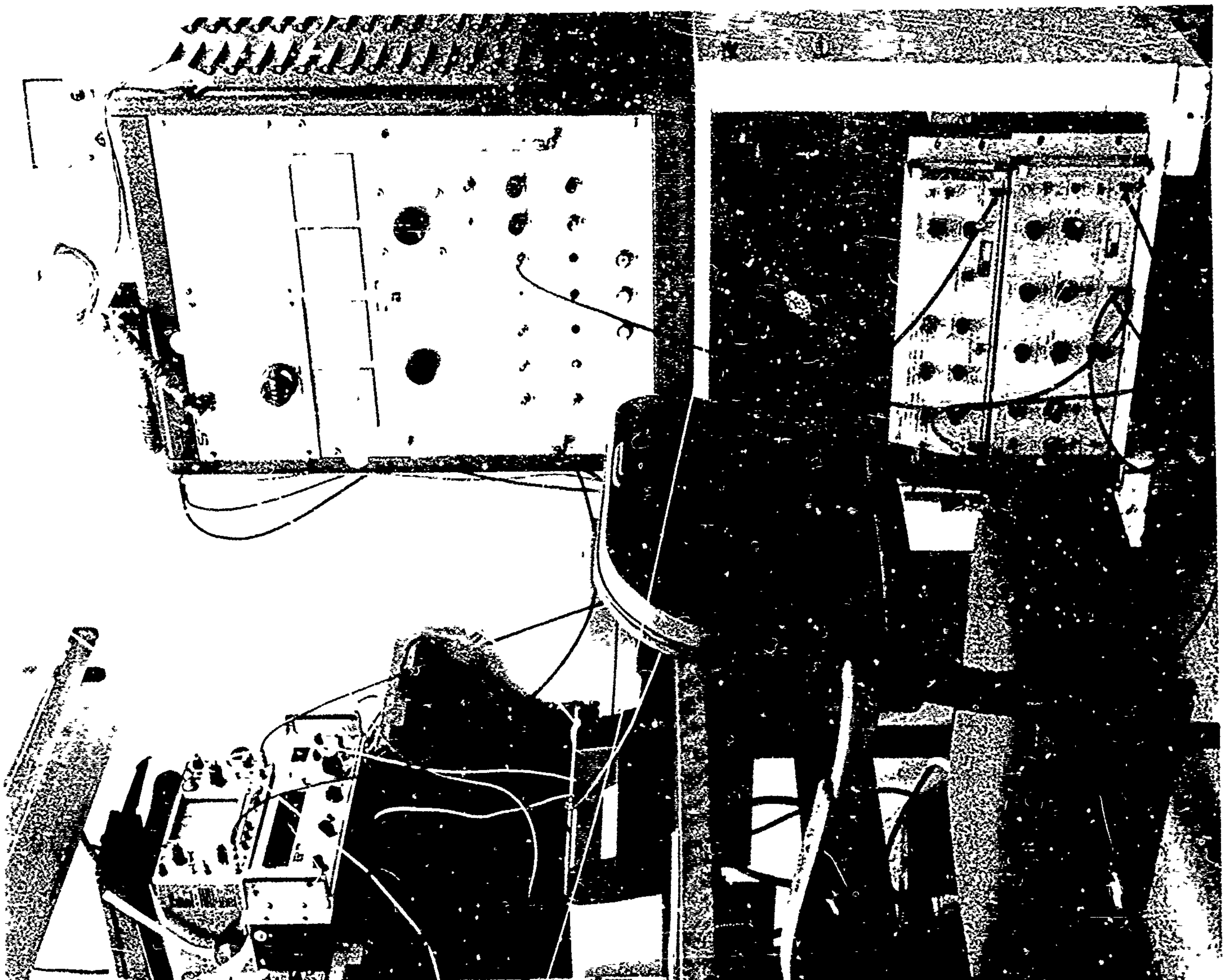
1.4 System Configuration.

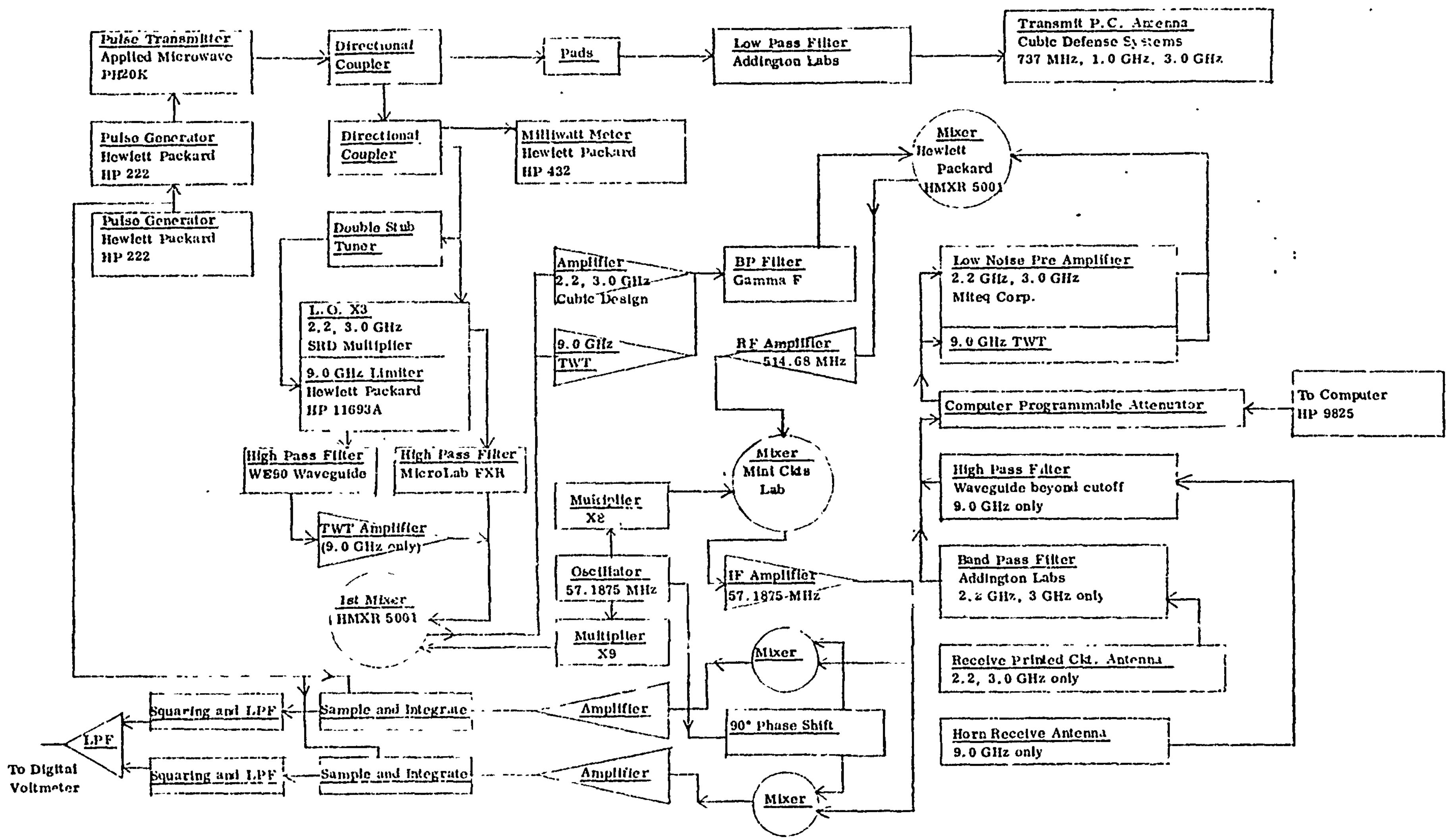
1.4.1 See Figure 1.4.2.

1.5 Condensed System Parameters.

1.5.1 Transmitter.

Mainframe: Applied Microwave Laboratory, Model PH20K





METHRA SIGNATURE TEST RECEIVER BLOCK DIAGRAM

Figure 1.4.2

1.5.1 (Cont'd.)

Plug-Ins:

Manufacturer:	Applied Microwave Laboratory, Inc.		
Model Number:	1703HB	1704H	1709H
Frequencies:	700 - 950 MHz	950 - 1220 MHz	2700 - 3100 MHz
Operating Frequency:	737 MHz	915 MHz	3.0 GHz
Output Power:	15 KW	15 KW	10 KW
Pulse Width:	1.0 microsecond		
Pulse Repetition Frequency:	1.0 KHz		

1.5.2 Receiver.

Type: Coherent - Triple conversion.

Receiving Frequencies:	2211 MHz	2745 MHz	9.0 GHz
Receiver Noise Figure:	3.0 dB max	3.0 dB max	3.5 dB max

1.5.3 Target Tests.

Antenna Height Above Ground: 6 Feet.

Antenna Angle: Parallel to earth's surface.

Antenna Polarization: Horizontal (targets are tested in three axes).

Transmitter Power Density at Target: 128 W/M^2, 64 W/M^2, 6.4 W/M^2, 0.64 W/M^2, .064 W/M^2, .0064 W/M^2.

Target Types:
Target Class A - Air Scatterable Anti-Tank Mine.
Target Class B - Artillery Delivered Anti-Personnel Mine.
Target Class C - Anti-Personnel Mine.

(Target Classes A and B encompass one group each with 4 samples per group. Target Class C consists of two groups with 4 samples per group. All targets are in the de-activated state.)

Nominal Spacing Between Antennas and Target: 14.5 feet, 4.42 meters.

2. DESCRIPTION.

2.1 Transmitter.

The Applied Microwave Laboratories Pulse Signal Source Model PH20K features interchangeable frequency plug-ins capable of pulsed emission in the 150 MHz to 6,000 MHz spectrum. The transmitter model owned by Cubic is no longer in production but plug ins for the current models are compatible by an interface cable provided by Applied Microwave. Test equipment at the transmit output is capable of a maximum power of 15 KW. The receiver coherent local oscillator is developed by sampling the transmitter output, multiplying the signal by three and amplifying to a nominal +7 dBm. The output power is monitored with a HP 432 wattmeter with appropriate power pads to adjust the power level. The computer controlled data taking equipment determines transmitter anomalies and provides a warning to the operator while stopping the data taking process.

The transmit power is calculated to provide 128 W/M^2 at the desired operating frequency. Lower power levels are adjusted by inserting pads in the transmit path to the antenna. Extreme care is necessary in this path to prevent leakage signals from developing high background noise levels.

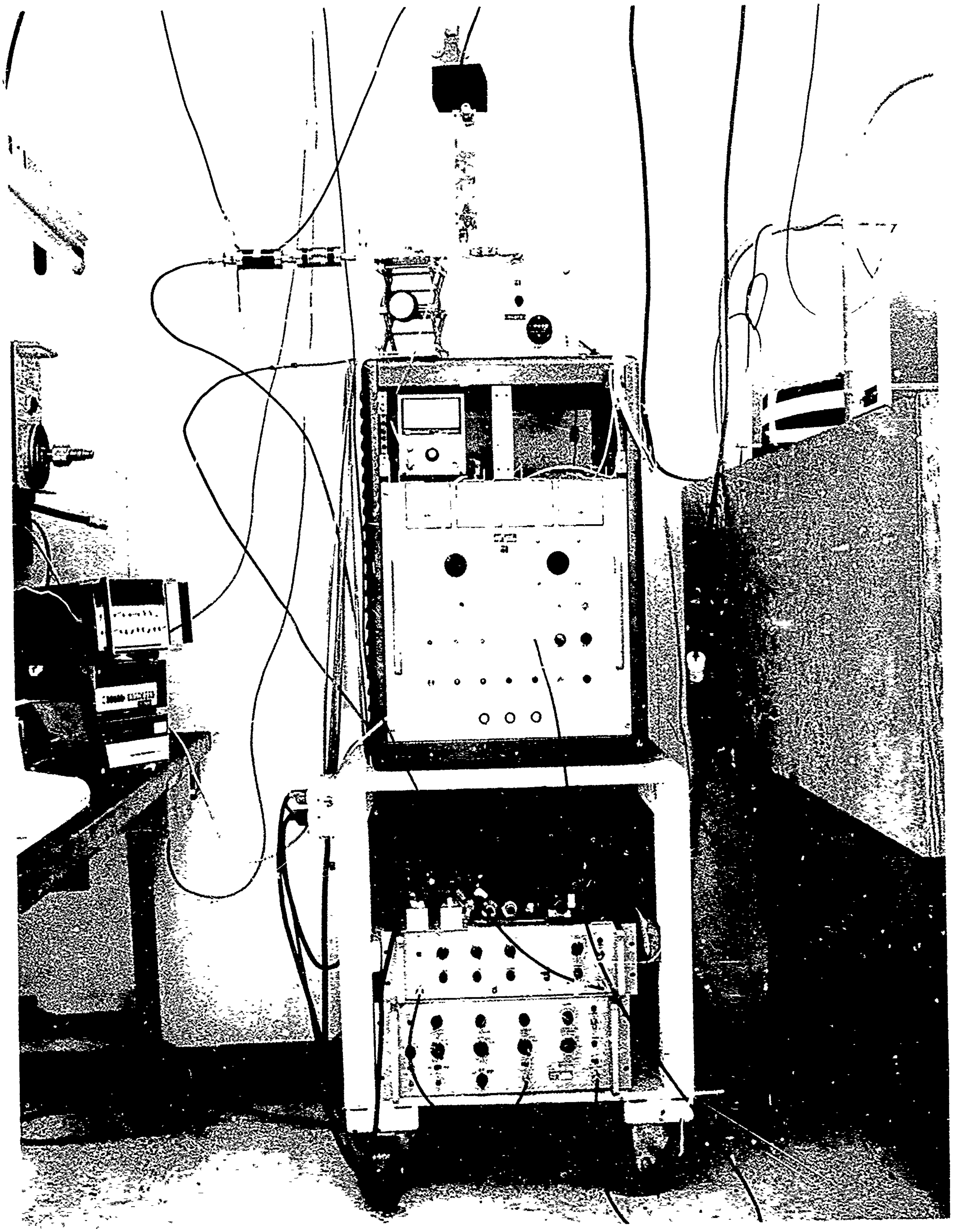
2.2 Transmit and Receive Filters.

The coaxial line transmit and receive filters are produced for Cubic Defense by Addington Laboratories. Techebychev designs are used for both filters to provide the steepest skirts for given numbers of reactive components. The METRRA Signature test configuration requires the filters to exhibit at least 184 dB of harmonic conversion loss at the third harmonic of the input signal, which dictates the following guidelines for construction and fabrication of the filters:

1. Minimize the number of metal to metal junctions in regions of high current density.

2. Reduce current densities wherever possible by avoiding resonance effects, increasing operating impedance levels and increasing the overall size of the devices.

3. Materials and surface treatment techniques must be non-oxidizing, exhibit smooth surfaces, and be free from microscopic cracks.



2.2 (Cont'd.)

It is particularly important to follow these guidelines in the transmit signal path since high power levels at f_0 can produce non linear harmonic generation. The output section of the transmit filter and the input portion of the receiver filter represent the most disastrous locations for harmonic conversion.

The following is a list of low harmonic conversion Addington filters purchased for the signature program:

103800461	Low Pass Filter	737 MHz
103800462	Low Pass Filter	1000 MHz
103800463	Low Pass Filter	1400 MHz
103800464	Low Pass Filter	2211 MHz
103800465	Low Pass Filter	2600 MHz
103800466	Low Pass Filter	3000 MHz
103800467	Band Pass Filter	2211 MHz
103800468	Band Pass Filter	3000 MHz

The construction features of the low pass and high pass filters are shown on figures 2.2.1 and 2.2.2 respectively. The electrical and mechanical design permits practical fabrication and assembly while it greatly reduces the probability of significant amounts of third harmonic energy reaching the transmit output. At the RF input, a standard type SMA connector is soldered to the tubular filter housing. The center contact of the connector is also soldered to the silver plated center element of the filter. Soldering is necessary at this location to eliminate RF leakage rather than attempting to obtain maximum linearity in the junctions. The harmonic energy at this junction is well below the third harmonic output of the transmitter, and is attenuated by the filter. The center element is machined from a solid brass bar and silver plated.

Harmonic generation is increasingly more critical closer to the output as a result of fewer attenuation sections remaining in the filter. The output of the filter is most critical where non linearities are eliminated to the maximum degree practical.

Coupling of the output coax center conductor to the center element of the filter is shown in Figure 2.2.1. A Teflon insulated quarter wave capacitive coupling section effectively replaces the solder connection normally found at the output of conventional filters and eliminates metal to metal harmonic junctions. The coax shield connection is soldered to the filter to prevent RF leakage.

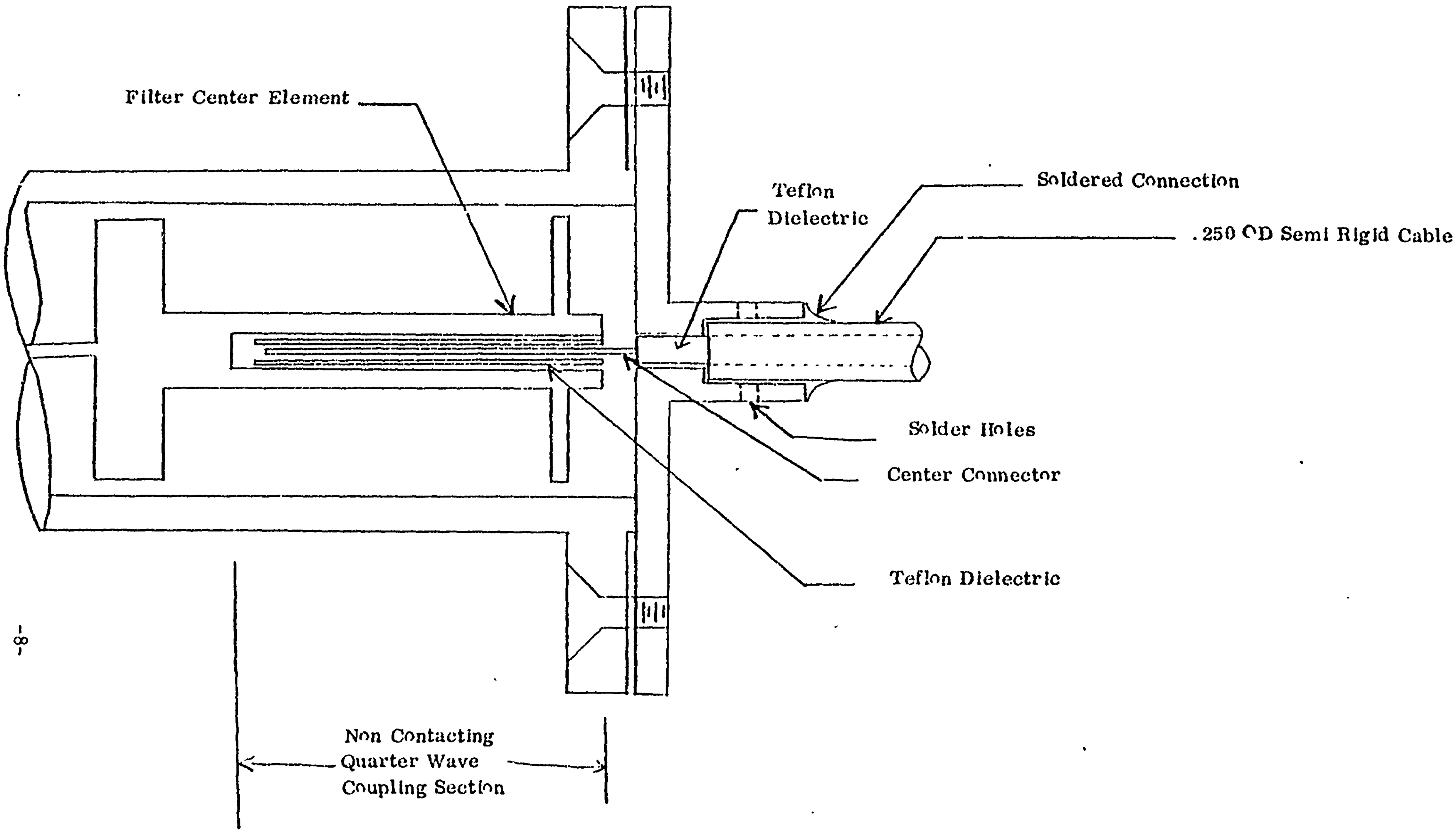


Figure 2.2.1
Transmitter Filter Construction

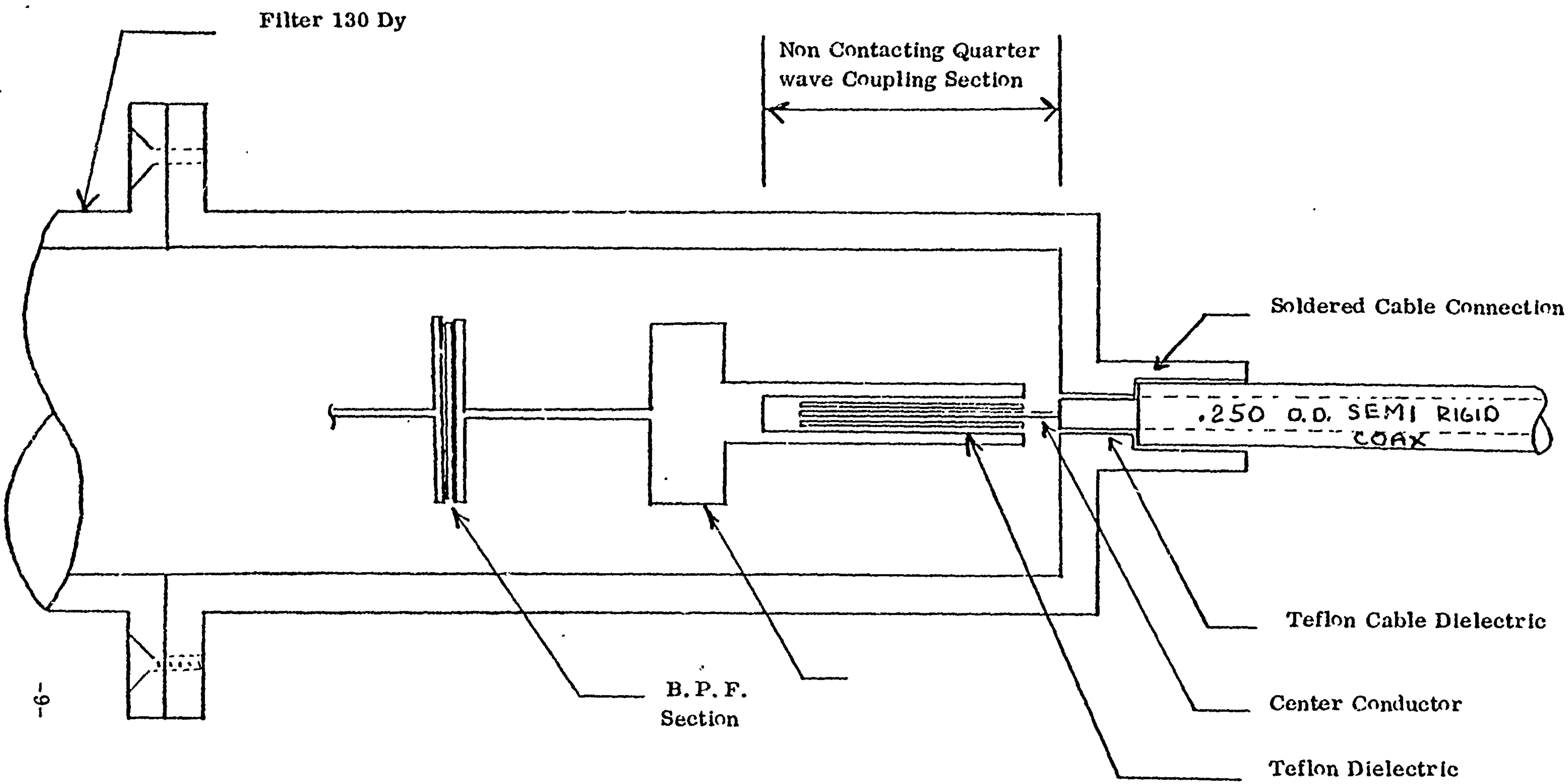


Figure 2.2.2
Receiver Bandpass Filter Construction

2.3 Receiver.

The METRRA Signature Receiver third IF and baseband circuits are identical in most respects to those used in the Cubic Man Portable METRRA program. The receiver boards are identical to previous Cubic designs with the exception of the sample and integrate circuit. The design was originally a sample and hold arrangement which was susceptible to short duration, high voltage noise spikes. Approximately 10 dB of additional sensitivity is achieved by integrating the voltage noise spikes.

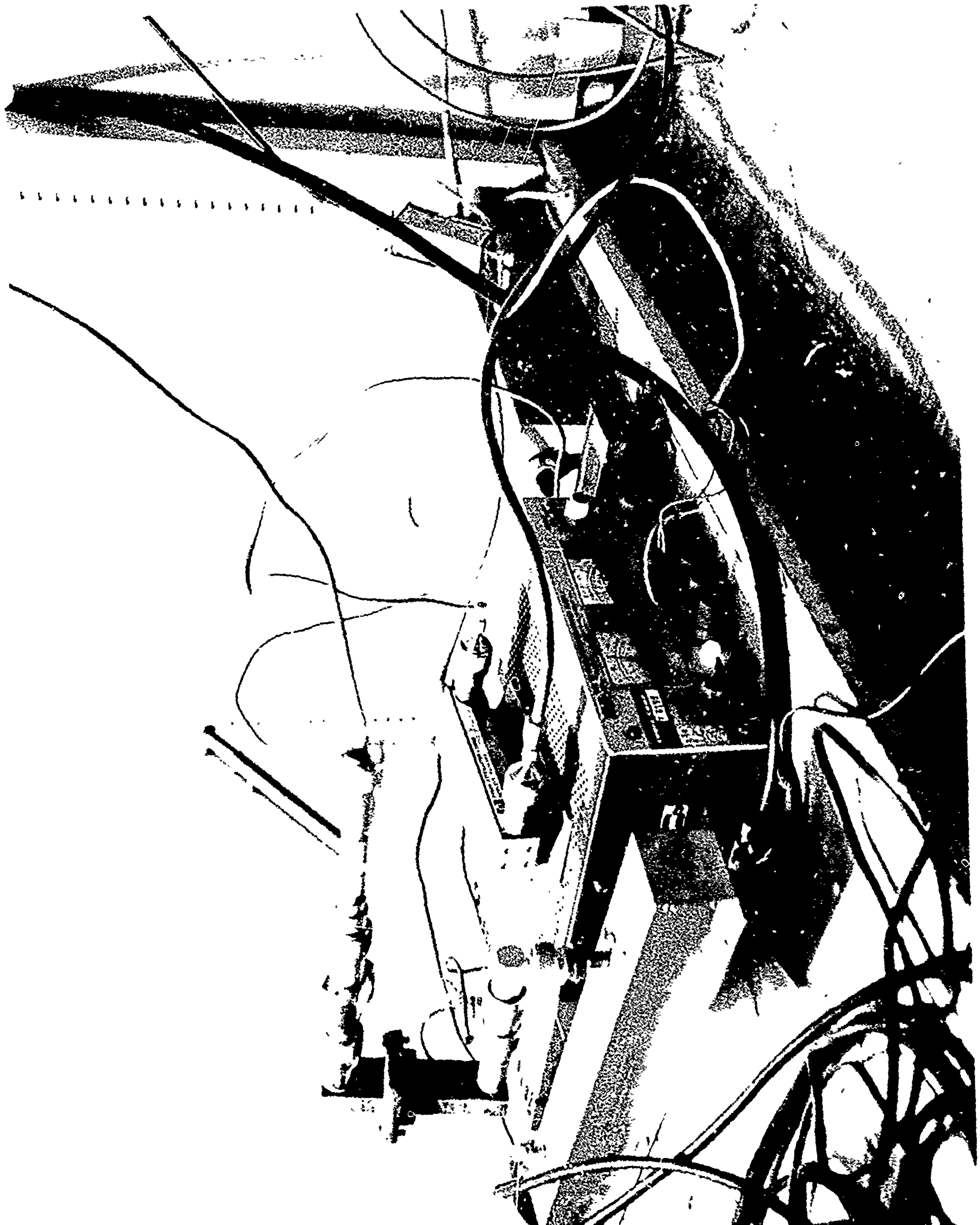
The first and second mixers are Hewlett Packard HMXR 5001 double balanced wide band devices with a RF input range of 2.0 to 12.4 GHz.

The X3 local oscillator is generated by the same circuit at 2.2 GHz and 3.0 GHz. At 2.2 GHz and 3.0 GHz, a step recovery diode circuit is followed by a Microlab FXR high pass filter. The same hardware is used at these frequencies by adjusting the circuit components to the new frequency.

At 9.0 GHz a passive Hewlett Packard Spectrum Analyzer limiter generates the third harmonic local oscillator signal. A high pass filter (WE 90 waveguide beyond cutoff), and TWT amplifier follow the multiplier stages to provide the LO.

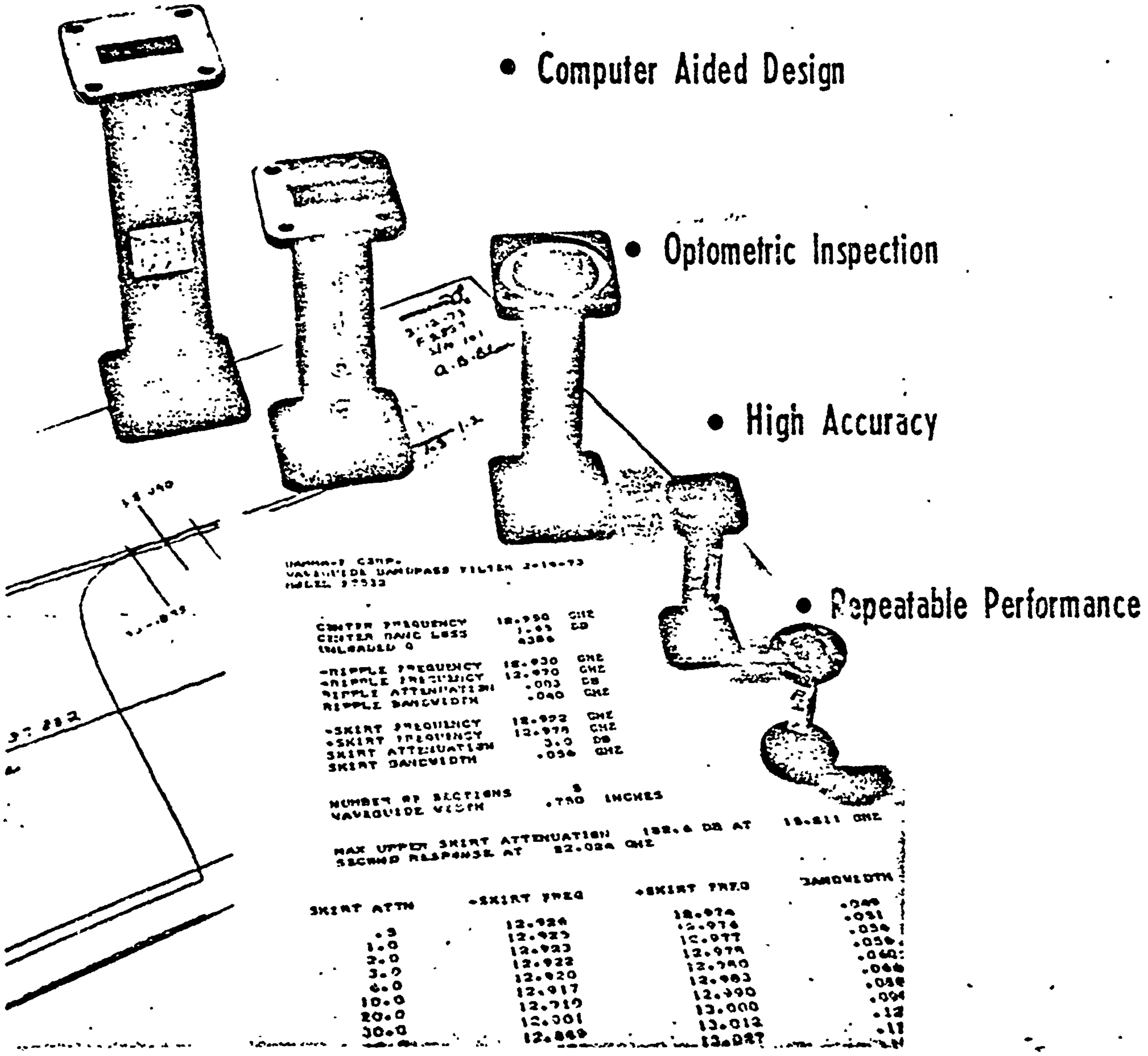
The Gamma F filters are electroformed waveguide structures which bandpass the mixer L.O. output. The Gamma F model numbers are F11297, F90050, and F9051. See Figures 2.3.1 and 2.3.2.

The noise figure is set at 2.2 GHz and 3.0 GHz by a low noise preamplifier manufactured by Miteq Corp. The noise figure of the receiver front end at 9.0 GHz is set by a low noise traveling wave tube amplifier.



ELECTROFORMED WAVEGUIDE FILTERS

DATA SHEET 102



Gamma-f offers complete capability in the design and manufacture of waveguide filters through millimeter wave, using the electroformed fabrication process for high accuracy, quality, and repeatable performance.

Filter requirements are first reviewed by our microwave engineering department. The requirements are then programmed into our computer for quick but accurate design computation. Values are computed for ripple bandwidth, selectivity characteristics (taking into consideration the waveguide dispersive effects), midband insertion loss, VSWR, group delay, and all critical mechanical dimensions for fabricating the actual filter.

Electroforming is Gamma-f's secret to fabricating repeatable filters to reproduce the computed electrical performance. Typical performance characteristics of filters designed and manufactured by Gamma-f are depicted in the tables. Filters are Chebyshev unless otherwise noted.

Brass cover flanges are standard. Choke flanges can be supplied on special order.

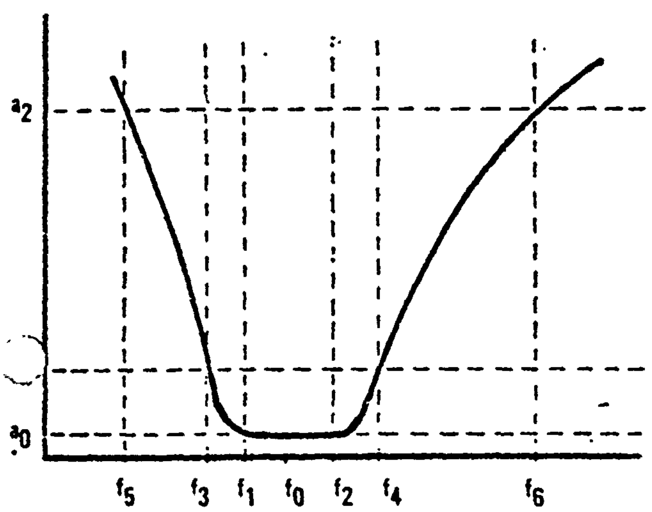
Fig. 2.3.1

TABLE II
Waveguide Bandpass Filters
TUNEABLE

Model No.	Center Freq. Tuning Range (GHz)	Insertion Loss (dB)	* 3dB Band-Width (MHz)	40dB Band-Width (MHz)	Number of Sections	Remarks
F-11209	7.75- 7.95	.7	45	210	3	WR-112
F-7502	12.2 -12.7	1.0	110	350	4	WR-75
F-7504	9.7 -10.7	2.5	30	75	5	WR-75
F-7505	10.7 -11.7	1.6	50	110	5	WR-75
F-7506	12.2 -12,7	1.8	50	110	5	WR-75
F-7507	10.7 -11.7	1.3	80	150	7	WR-75
F-7508	12.2 -12.7	1.3	80	150	7	WR-75
F-7510	10.7 -11.7	2.5	20	100	3	WR-75 Butterworth
F-7512	12.7 -13.2	1.0	115	330	4	WR-75
F-7513	10.5 -10.7	1.0	115	330	4	WR-75
F-7514	10.7 -11.2	1.0	115	330	4	WR-75
F-7515	11.2 -11.7	1.0	115	330	4	WR-75

TABLE III
Waveguide Bandstop Filters
FIXED TUNED

Model No.	Center Freq. (GHz)	3dB Band-Width (MHz)	50dB Band-Width (MHz)	Number of Sections	Remarks
F-2849	36.78	600	200	6	WR-28
F-2850	38.09	600	200	6	WR-28
F-2853	36.82	800	300	6	WR-28
F-2854	38.06	875	350	6	WR-28
F-2877	37.40	400	200	7	WR-28
F-2879	38.01	2500	600	5	WR-28
F-2880	36.86	2350	600	5	WR-28
F-2888	36.79	2400	600	5	WR-28
F-2889	38.09	2700	600	5	WR-28



ORDERING INFORMATION

For filter requirements not shown in Tables I, II, or III specify your requirements with symbols as follows:

f_0 = center frequency
f_1, f_2 = signal band (minimum)
f_3, f_4 = 3 dB passband (minimum)
f_5, f_6 = frequencies at a_2
a_0 = maximum midband loss (dB)
$a_1 = a_0 + 3$ dB
a_2 = minimum rejection (dB)

Fig. 2.3.2

2.4 Antennas.

2.4.1 Requirements.

There are eight (8) identifiable properties of an antenna system suitable for application in the METRRA Signature Measurement Program:

(1) Linearity
(2) Gain
(3) Uniformity over Target
(4) Power
(5) Frequency
(6) Collocation
(7) Polarization
(8) Cost

2.4.1.1 Linearity.

The antenna is free of metal-to-metal contacts or other non linear elements that would introduce spurious third harmonic radiation and thereby obscure the third harmonic radiation from the target. This requirement is the most critical and is unique to this application. As discussed below, Cubic has a proven technique to meet this requirement.

2.4.1.2 Gain.

To obtain the specified power densities with reasonable transmitter outputs, the antenna provides 15 to 20 dB gain above isotropic.

2.4.1.3 Uniformity over Target.

The nature of the third harmonic back scattering phenomenon is not perfectly understood. As a result, it is essential that experimental data be collected in as nearly as real-world environment as possible. In terms of the antenna requirement, this means that the electromagnetic fields over the target must be uniform as possible, to simulate the field distribution that would be associated with an antenna far field. Since the ultimate application and earlier measurements are both far-field situations, this requirement assumes critical importance. The classical trade-offs between antenna gain (related direct-

2.4.1.3 (Cont'd.)

ly to linear dimensions of the antenna) and the distance to the far field in which the uniformity of phase and amplitude are met must be addressed in the selection of the antenna size and type. In the actual experimental program, probing of the amplitude variation across the space to be occupied by the target confirms the validity of the selection.

2.4.1.4 Power.

Cubic used transmitting equipment and filters to deliver up to 10 kilowatts of peak power to the antenna. The antenna is capable of handling this power level safely without dielectric voltage breakdown or other loss of performance.

2.4.1.5 Frequency.

To minimize the number of antennas required, a combination of antennas operating at both the fundamental and third harmonic frequencies are used for as many of the target test frequencies as feasible.

2.4.1.6 Colocation.

To simulate the ultimate application, the transmitting and receiving antennas are located in the same volume of space relative to the illuminated target.

2.4.1.7 Polarization.

Although it is ultimately desireable to conduct some investigation into the sensitivity of the back scattering phenomenon to incident polarization, for purposes of this program, only vertical linear polarization is used. This simplifies the antenna requirement and permits use of the proven Cubic technique.

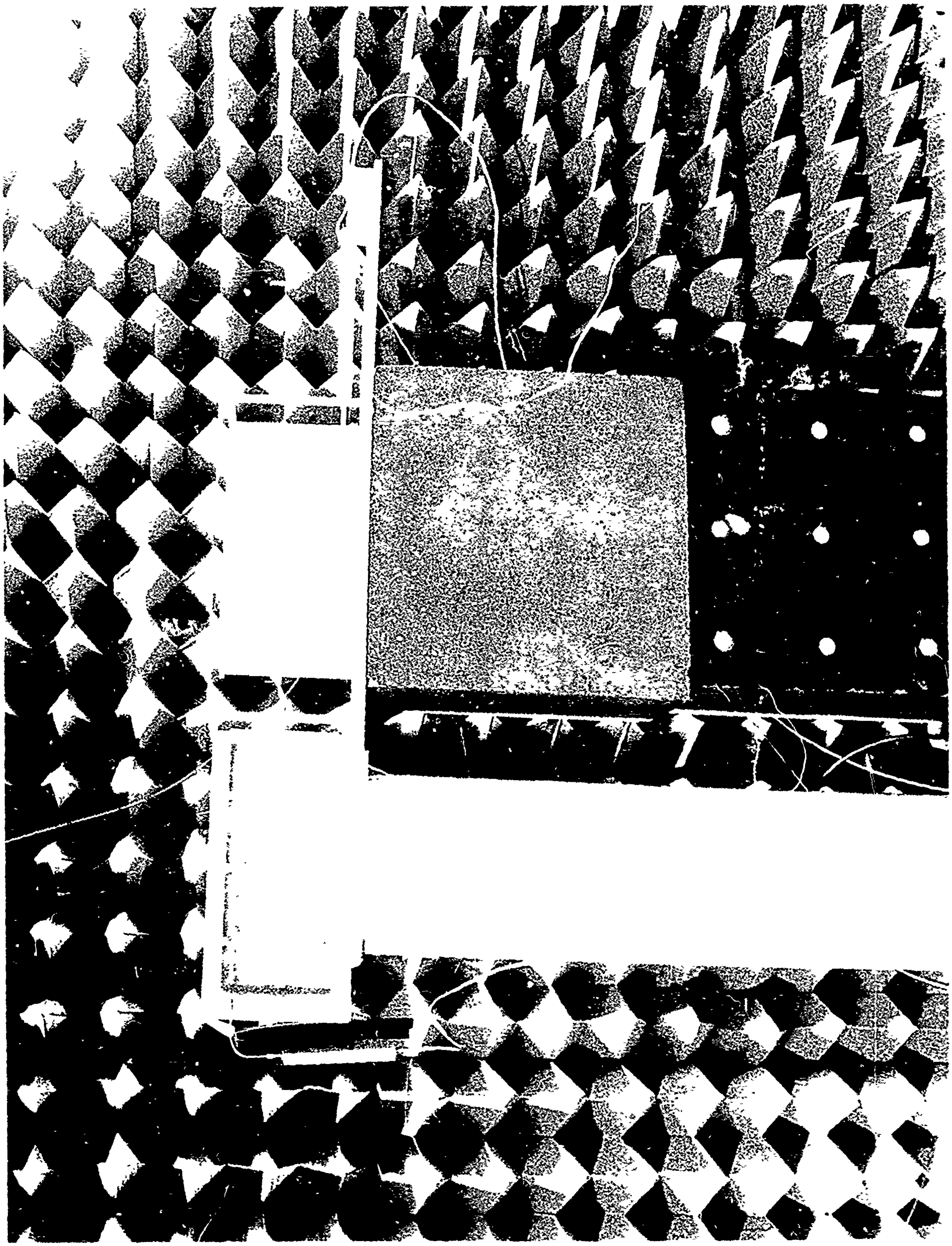
2.4.1.8 Cost.

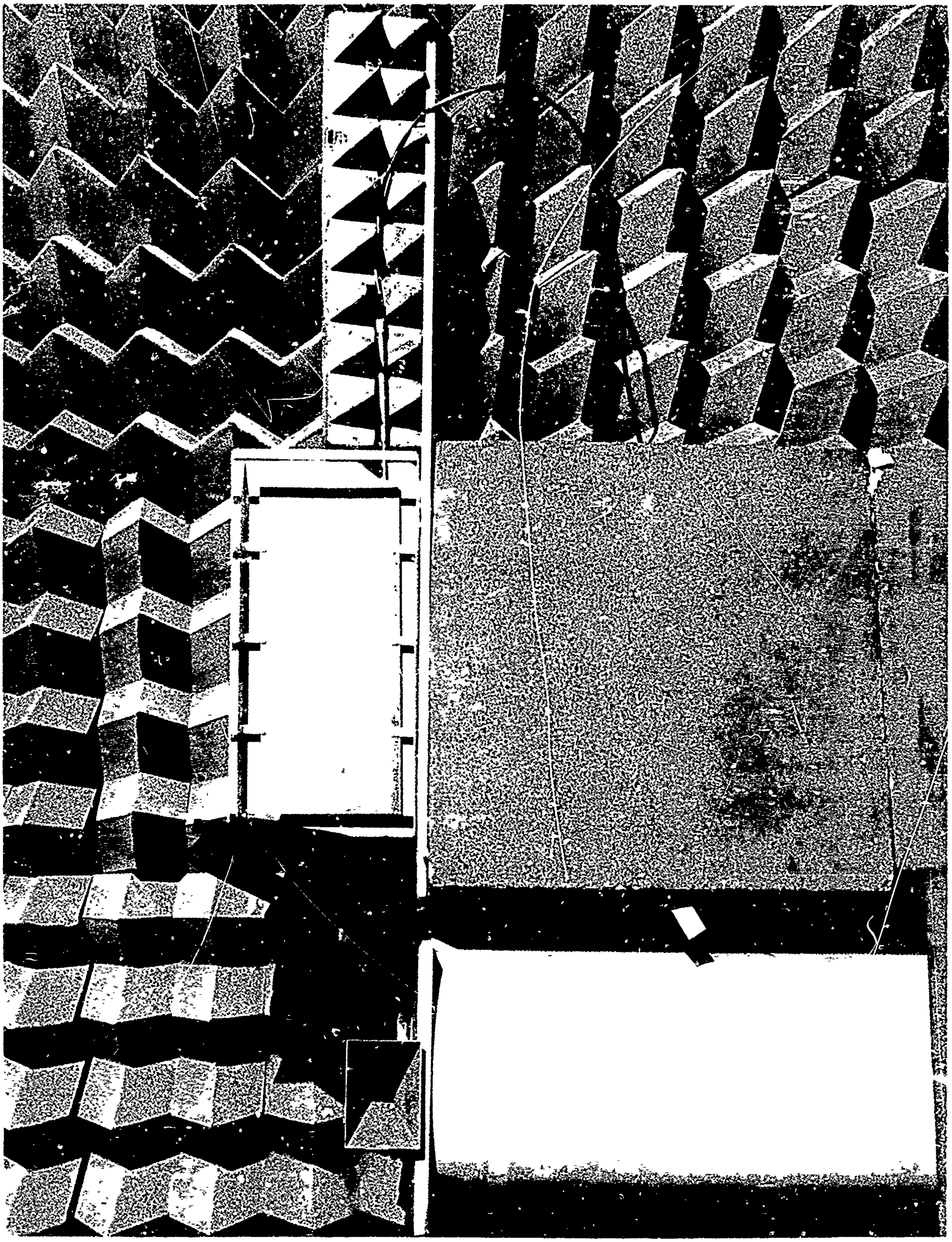
Since the objective of the program is to obtain and analyze data, hardware costs are to be kept to a minimum. Consequently, the antenna design selected is capable of fabrication at minimum cost and with little or no special design effort.

2.4.2 Physical Considerations.

The antenna is an array of dipoles fed in phase and positioned over a simulated ground plane to obtain increased directivity and to isolate the equipment in back of the antenna from the fundamental radiation.

For the man-packed METRRA the requirement was for an extremely light-weight antenna, in a minimum volume. For the back scatter signature measurements, these constraints are not observed. The transmitting and receiving antennas are essentially colocated, but the receiving antenna is screened from the transmitting antenna by a conducting or absorbing sheet. This separation increases the isolation from the spurious third harmonic radiation which can result if the receiving antenna is illuminated with the full transmitted power or a major fraction thereof.





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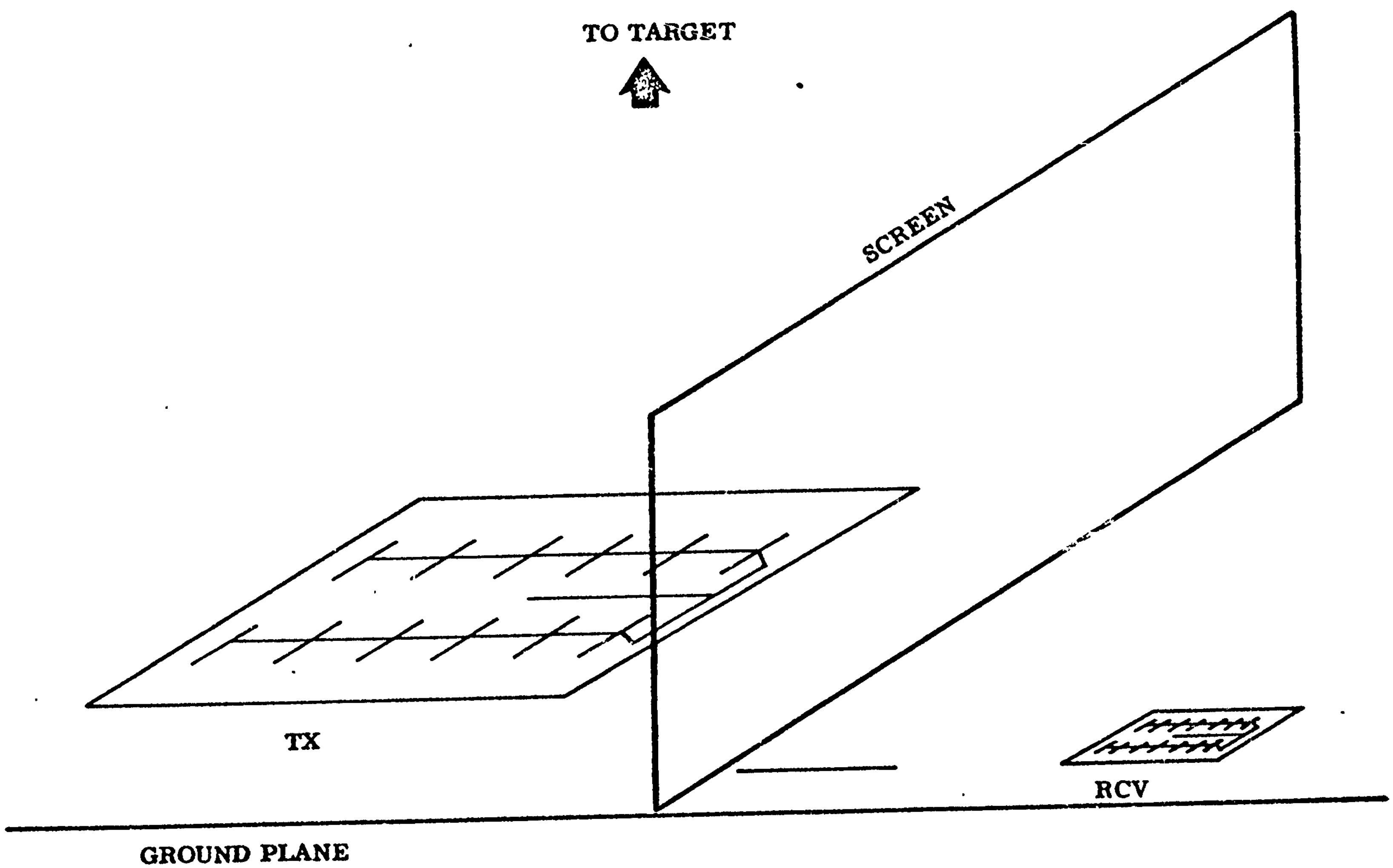


FIGURE 2.4-3
DUAL ANTENNAS

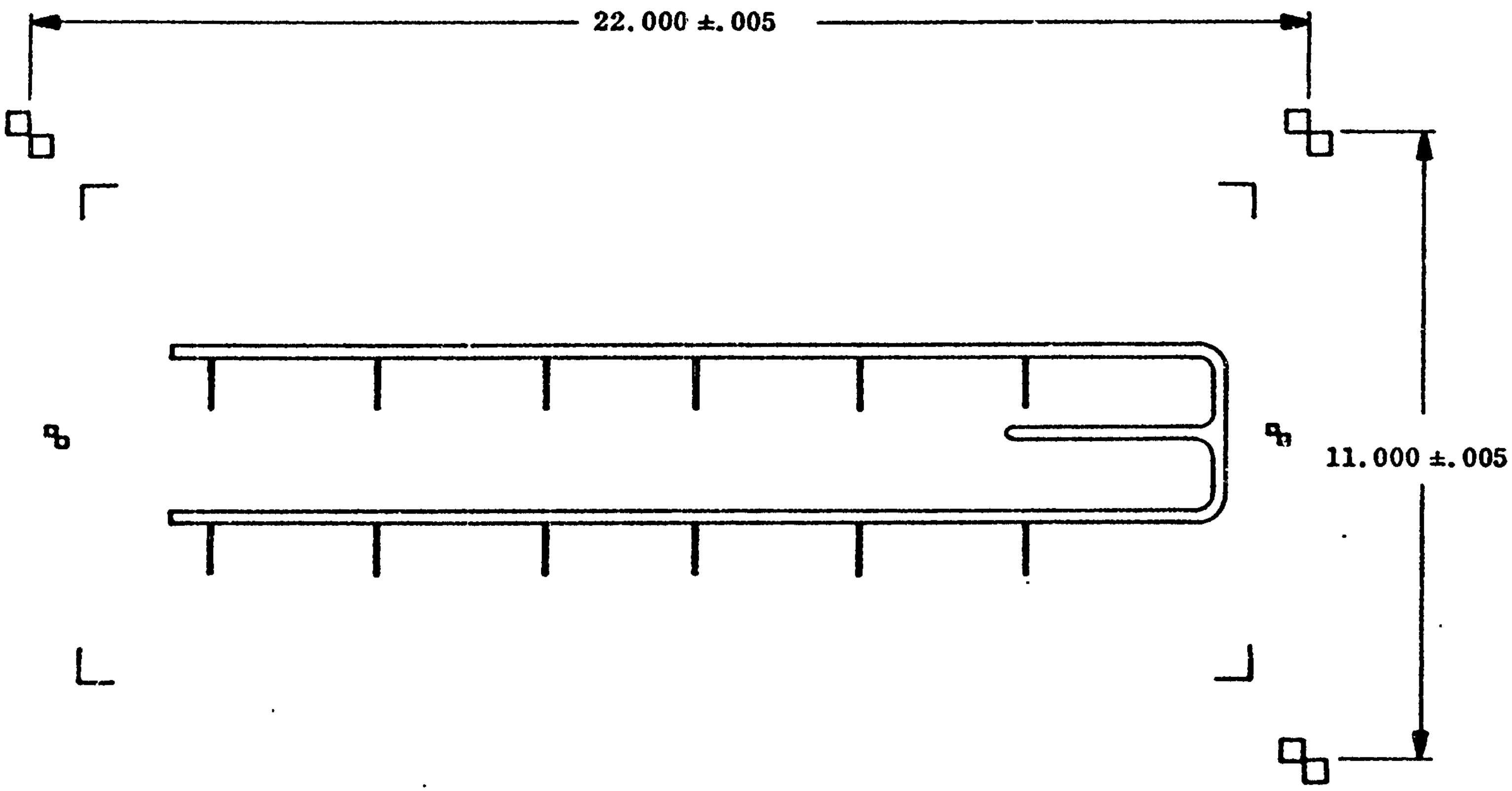


FIGURE 2.4-4
RECOMMENDED DIPOLE ARRAY, FRONT VIEW

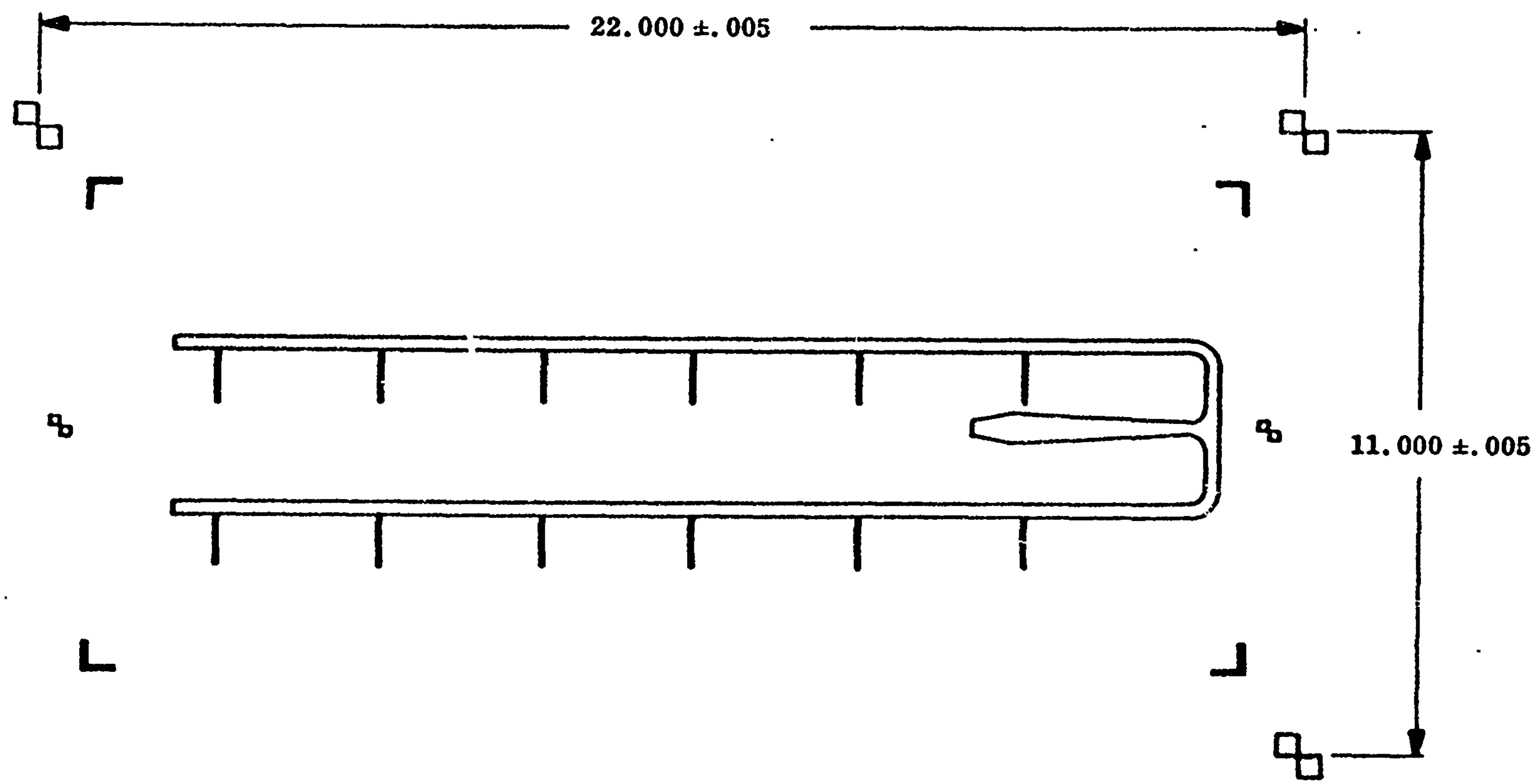


FIGURE 2.4-5
RECOMMENDED DIPOLE ARRAY, BACK VIEW

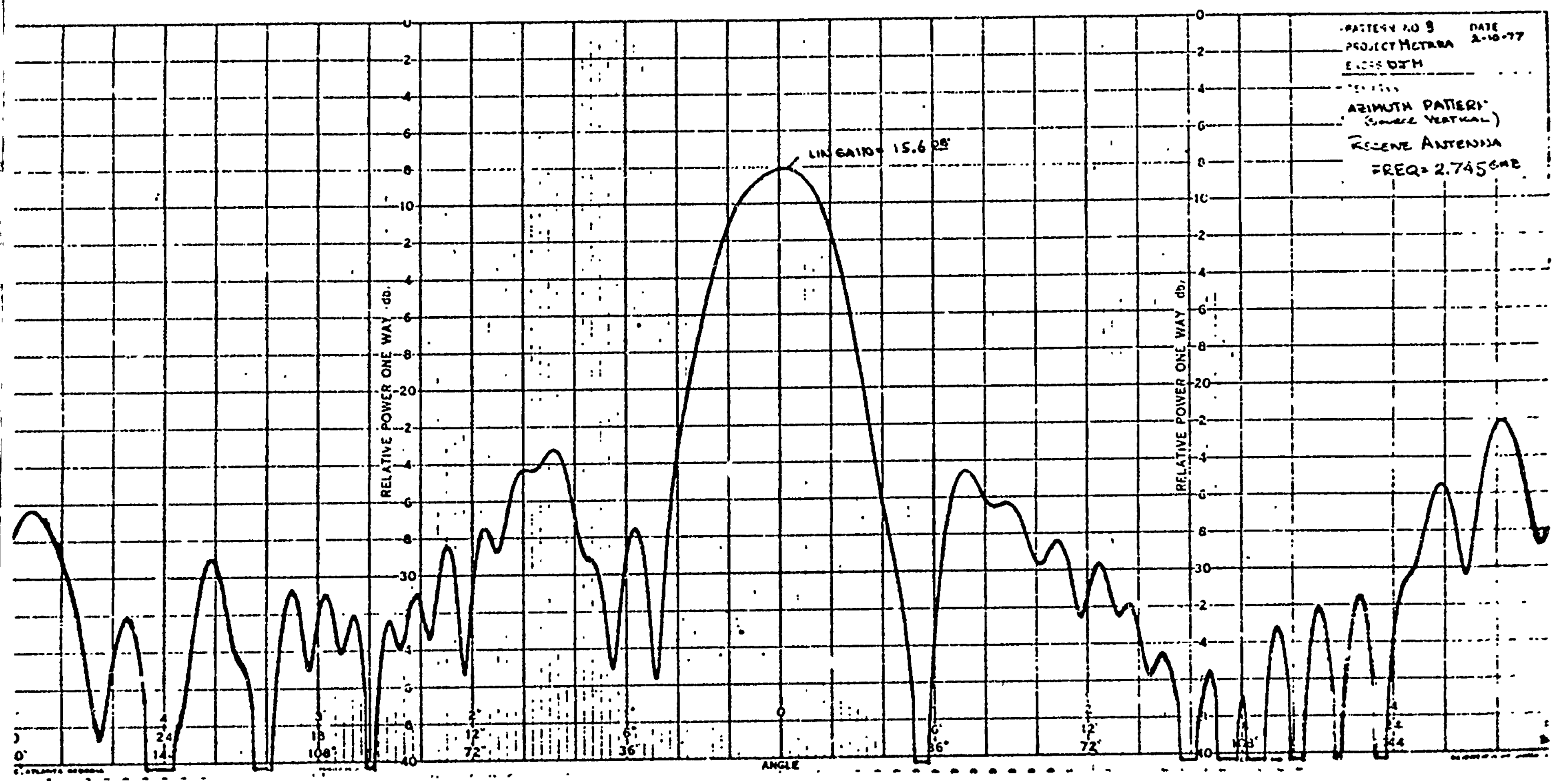


FIGURE 2. 4-6
RADIATION PATTERN NO. 3

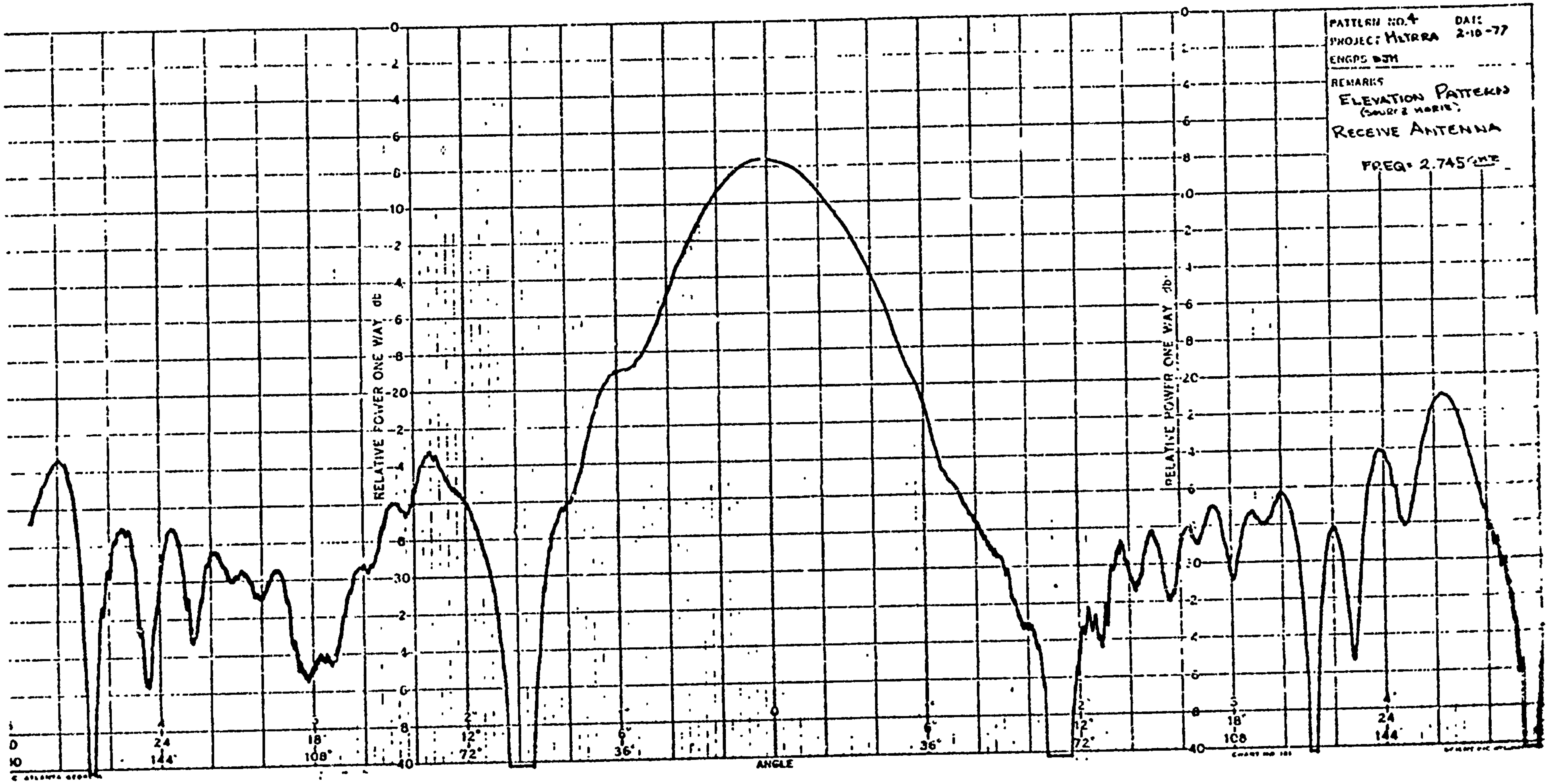


FIGURE 2.4-7
RADIATION PATTERN NO. 4

2.5 Data Collection.

All testing is performed under computer program control by a Hewlett Packard 9825 calculator. Target rotation, receiver calibration and receiver output are software controlled to facilitate testing, analyzer system performance and format data for easy retrieval and manipulation.

2.5.1 Calculator Program.

A program for the HP9825 computer is described which performs orderly (or even random) acquisition and storage of METRRA harmonic radar cross section data. Storage medium is magnetic tape to facilitate data recall in a random fashion and facilitate financial economy.

2.5.2 Required Data.

The test parameters recorded are classified as follows:

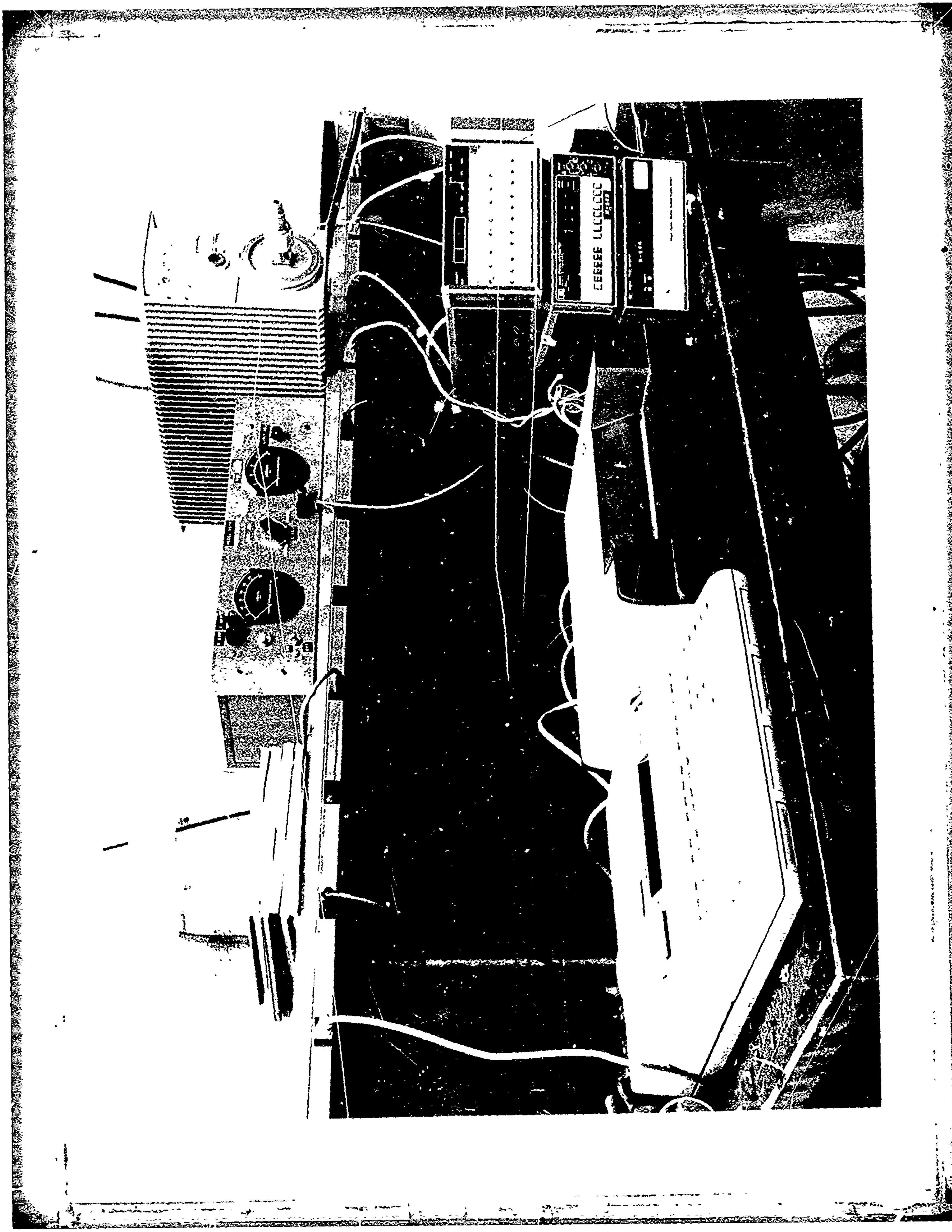
1. Specified constant quantities:
   a. Frequency
   b. Target power density.

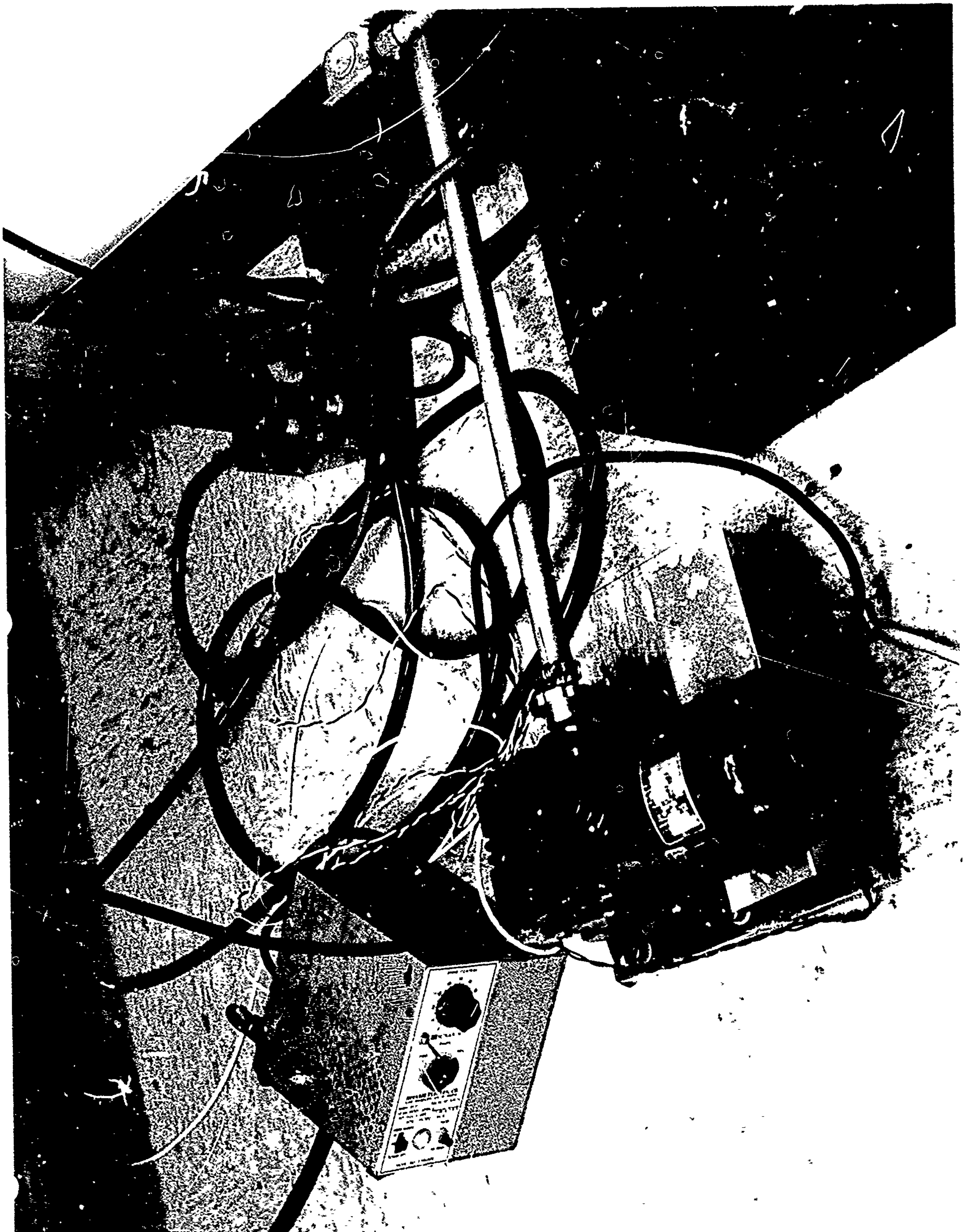
2. Measured variable quantities:
   a. Receiver voltage.
   b. Receiver input attenuation value.

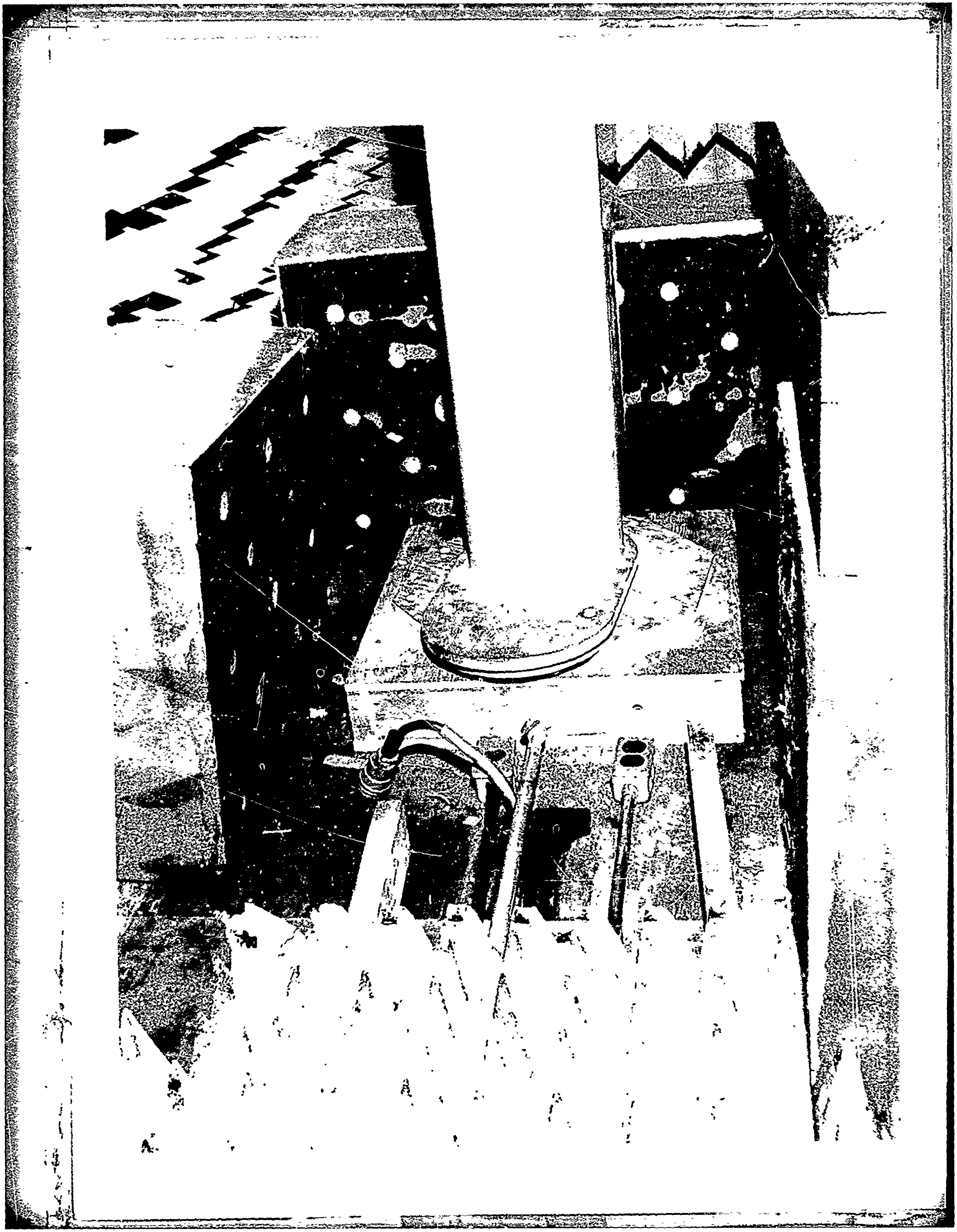
3. Target Identifiers:
   a. Target Type.
   b. Target No.

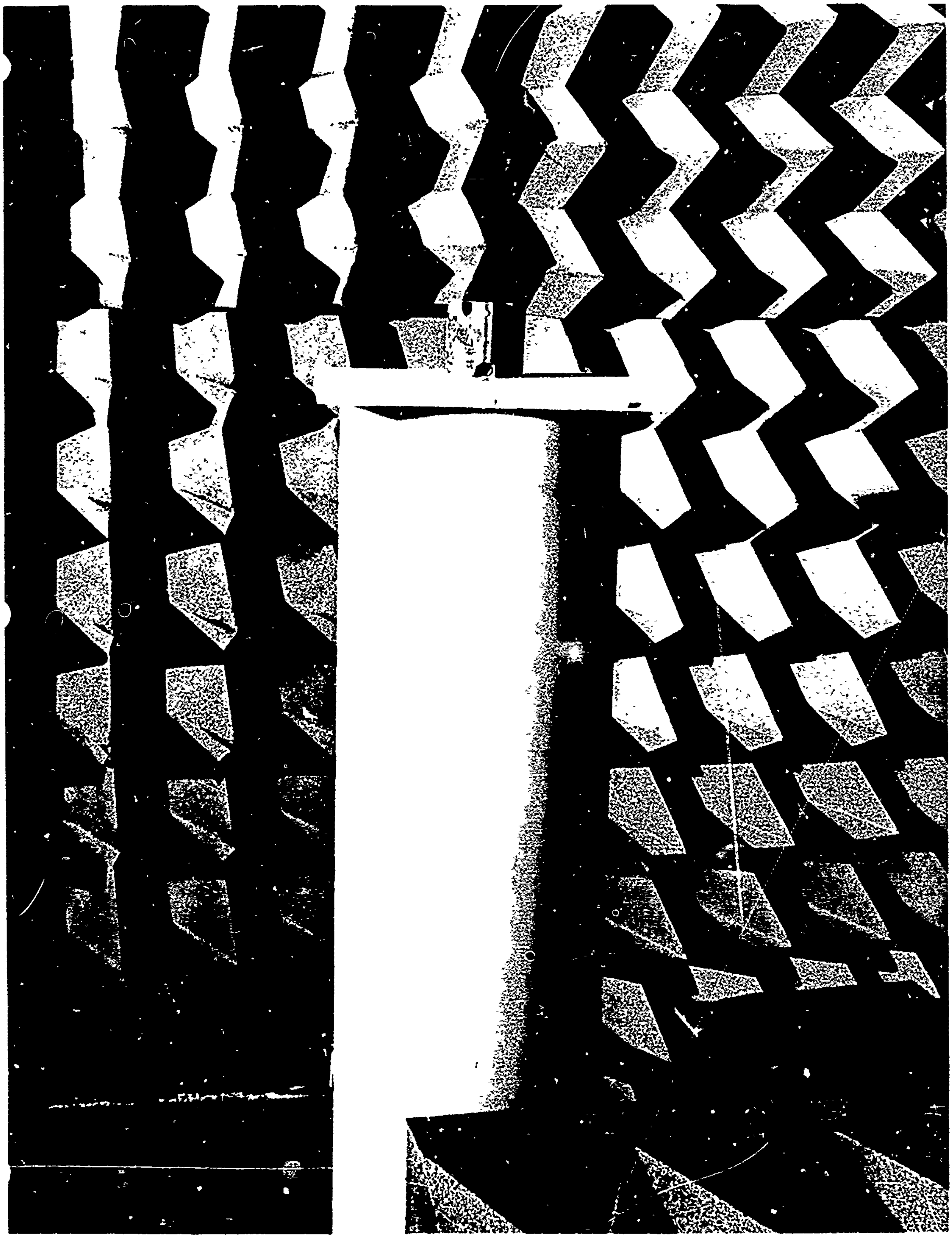
4. Measurement Identifiers:
   a. Plane of rotation.
   b. Azimuth position.
   c. With or without ground plane

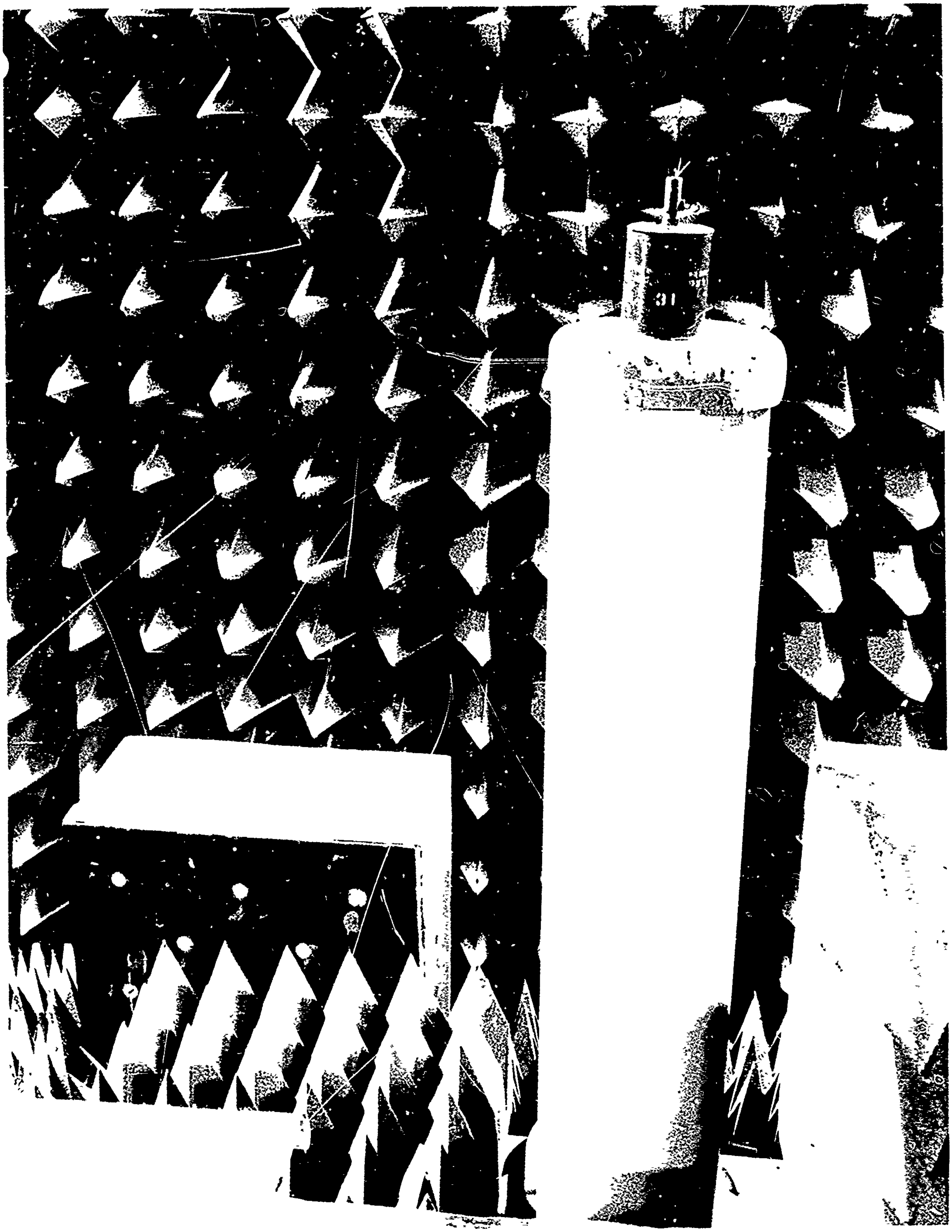
5. Miscellaneous Test Information:
   a. Data and Time.
   b. Test personnel.
   c. Climatic conditions in chamber.











2.5.2 (Cont'd.)

Each of these parameters take a finite number of values. These are listed below:

6 Frequencies
4 Target Types (Code)
4 Target Numbers
3 Plane of Cut
6 Power Densities
8 Aximuth Positions
2 Data Values/Azimuth (position with or without ground plane constitutes two more conditions).

From this, it is evident that the total data storage requirement is as high as 55,296.

2.5.3 Data Storage Format.

The following data format is established with the available tape storage capacity and I/O efficiency taken into consideration.

Each tape consists of two tracks and is subdivided into numerous data files. The files are of varying length and accessed individually or at random. All data in any particular file must be read. However, data that is not needed may be disregarded. Though the storage capacities of each tape are extensive, the data storage requirements of the METRRA project make the use of multiple tapes a logical approach.

Six tapes are used, one for each frequency. Track 0 of each tape will store only data taken without ground plane while Track 1 will store data with ground plane.

Since there are four target types and four samples of each target, 33 files are marked on each tape as illustrated in Figure 2.5-9. The first file (file #0) is an index, and files 1 to 16 are primary storage for the 16 targets. Hence, each target has its own file. Files 17 to 32 are back-up files. When data in the primary files is repeated for any reason, the program automatically stores the new data in a back-up file and updates the index in File #0 to correlate primary files and the appropriate back-up files. Note that a limited number of back-up files are accessable. All 16 back-up files may be used for any or all of the primary files.

2.5.3 (Cont'd.)

Each file is organized into blocks, heading blocks, index blocks, or data blocks (See Figure 2.5-10..

Heading blocks contain three 80 character lines. The first line is computer prompted comments, the second line miscellaneous comments prior to the data run and the third line miscellaneous comments following the data run and just prior to storage. Computer prompted comments include:

Target Type:	Hand grenade, etc.
Target Code:	A, B, C, D (to correspond with the target types)
Target #:	1, 2, 3, 4
Date and Time:	
Test Personnel:	
Ground Plane:	With or Without .

The index block serves to identify which cuts and power levels are measured during the test under the current heading. This block consists of an array of "Y's" and "N's".

For example, if all cuts at a power level of 128 watts/sq. meter were taken, then the index block would look like:

Y N N N N N
Y N N N N N
Y N N N N N

The data block of each file represents the data culminating from all the run data stored in that file. Any attempt to write over existing data in a file will automatically result in storage of repeat data in a back-up file and an update of the index file.

No more than five pairs of Heading/Index blocks are stored in a file at one time. Any entries above five over write the first entry, displays a warning on the printer and forces the program to stop and present ERROR MESSAGE on the computer.

2.5.4 Program Use.

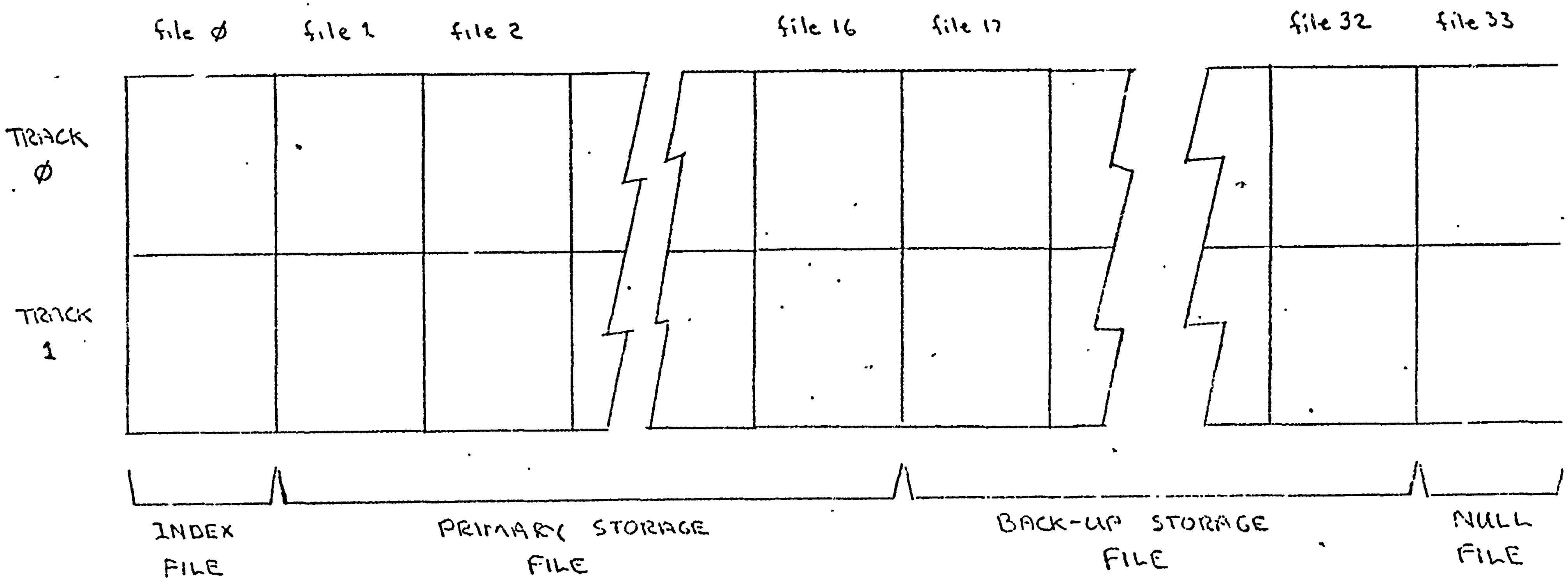
Step 1. Turn on 9825: Insert program tape.

Step 2. Key in rew; 1 dt, press execute.

Step 3. Insert METRRA data storage tape for the appropriate frequency and press run.

Step 4. After each entry of measured parameters or response to computer questions, press continue.

See Figure 2.5-4 for block diagram of program.



DATA TAPE FORMAT

FIG. 2.5-9

DATA FILE FORMAT

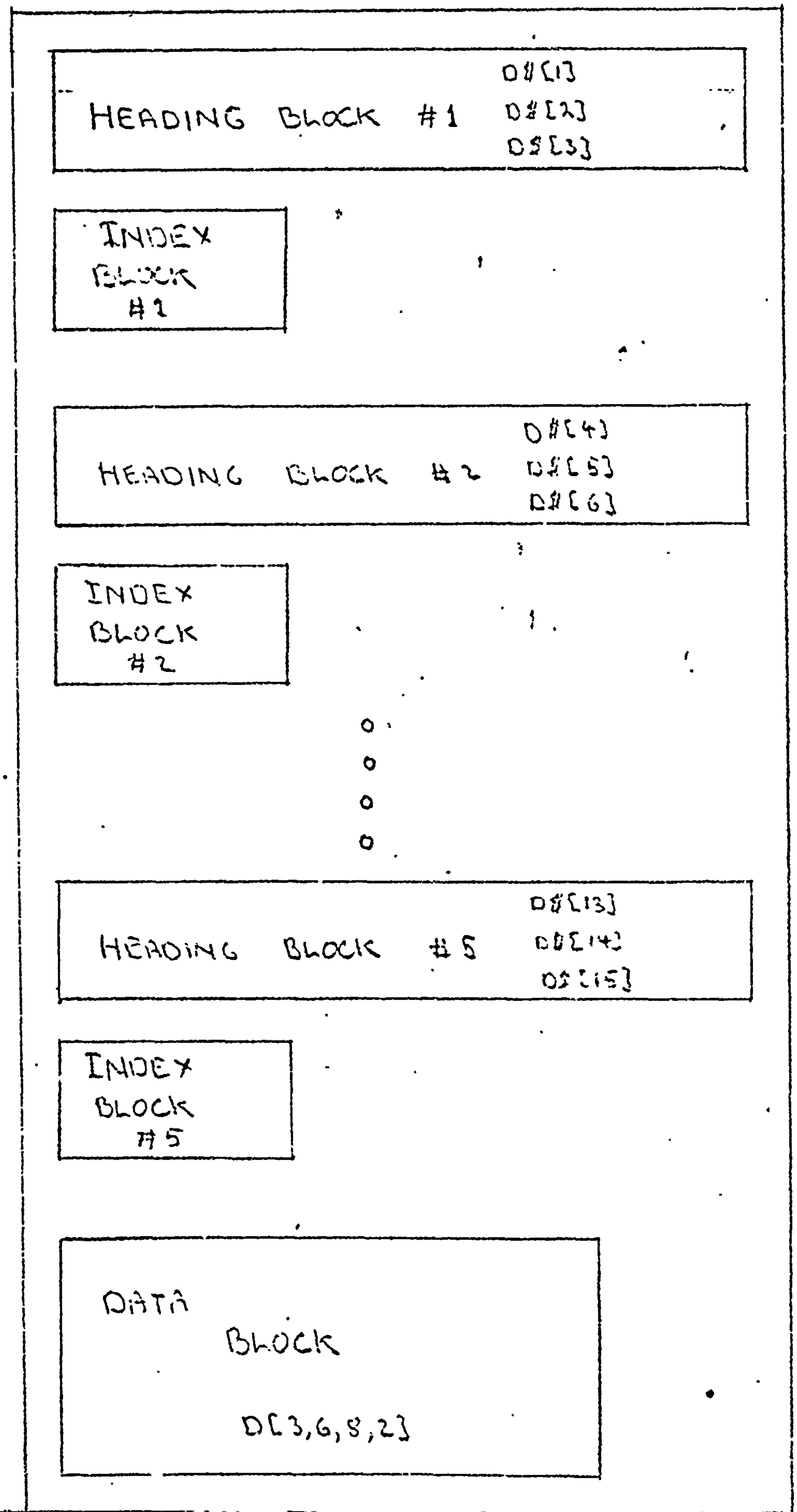


FIGURE 2.5.10

Plane of Cut

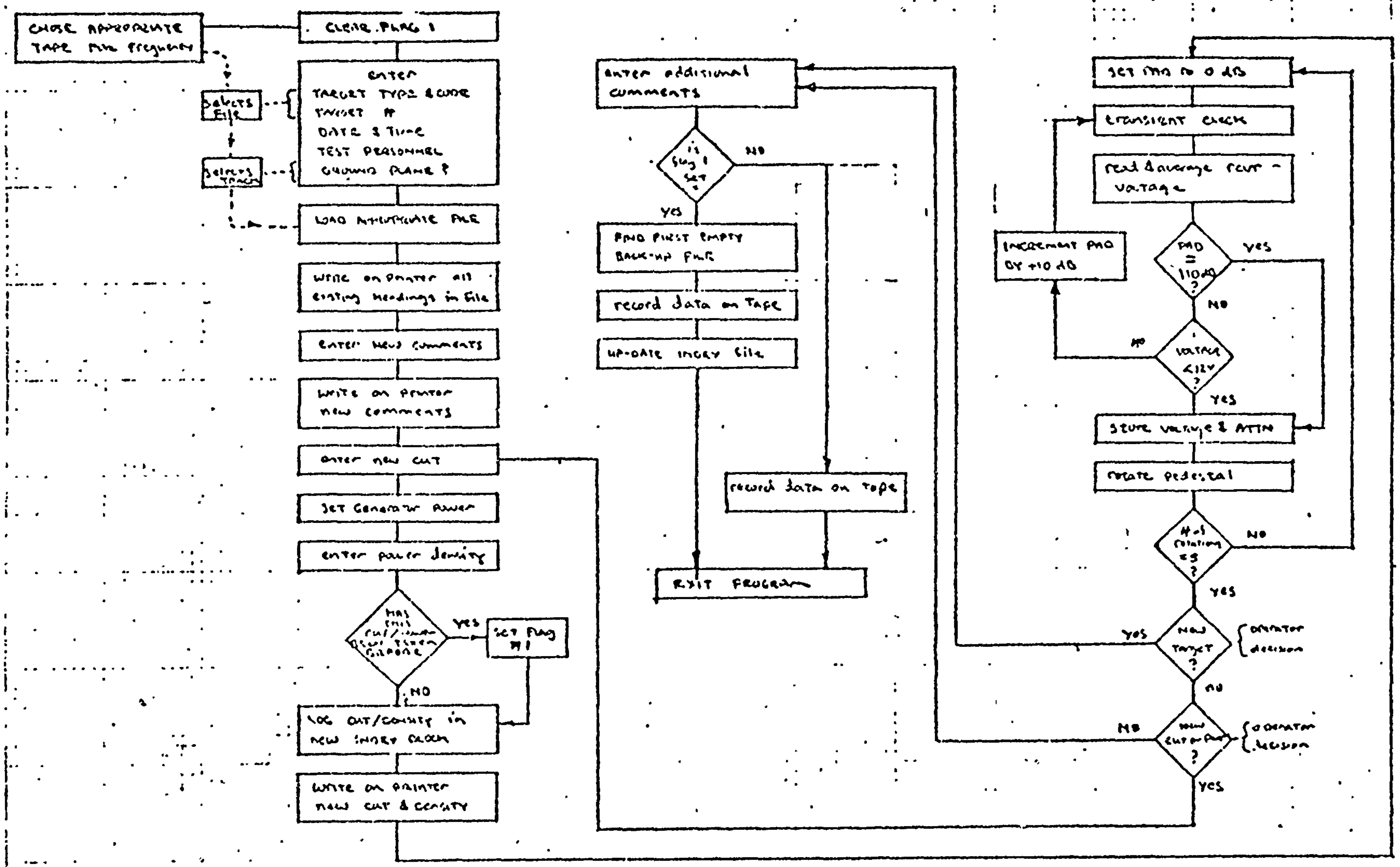
X - Y	N	N	N	N	N	N
Y - Z	Y	N	N	N	N	N
Z - X	Y	N	N	N	N	N

Power Density At Target

.0064 Watts/SqM
.064 Watts/SqM
.64 Watts/SqM
6.4 Watts/SqM
64 Watts/SqM
128 Watts/SqM

Y's: indicate measurement data was taken and recorded in data block.

N's: indicate measurement data was not recorded.



METRA DATA ACQUISITION PROGRAM FLOW CHART.

FIG 2.5-11

2.5.5 Signature Data Collection Calculation Sequence.

2.5.5.1 Record under computer control the following:

- Receiver Detector Voltage (complete mean of 20 samples).
- dB attenuation ahead of receiver.
- Target orientation.
- Target type.
- Target number.
- Transmitter Power Output.
- With or Without Ground Plane.

2.5.5.2 Convert receiver calibration data for computing power at the receiver given detector voltage and dB insertion loss ahead of the receiver.

2.5.5.3 Compute target signature and background signature.

2.5.5.4 A. Compute signature mean of each target vs. target orientation. (3 data points/power level).

B. Compute signature mean of target vs. cut. (8 data points/power level).

C. Compute signature mean and standard deviation of target vs. power. (24 data points).

D. Compute signature mean of the twice daily empty chamber data.

E. Subtract signature mean of targets vs. power by the signature mean of the empty chamber at 0.0064 W/M^2 and 0.064 W/M^2. Average the two results to yield a background correction factor.

F. Multiply the averaged correction factor by the background data to yield a corrected background signature level.

G. Compute target signature and background.

H. Correct for target background.

I. Compute least squares on 128 W/M^2, 64 W/M^2, 6.4 W/M^2, .64 W/M^2, .064 W/M^2, .0064 W/M^2, of all four target samples without background correction.

J. Repeat I with background corrected.

K. Repeat I and J above at 128 W/M^2, 64 W/M^2, and 6.4 W/M^2.

L. Repeat I, J, K for each target individually.

737MHz/2211MHz RECEIVER CALIBRATION DATA

Pi	Vo	
-125 dbm	First Movement	
-121 dbm	25 mv	
-118 dbm	50 mv	
-115 dbm	100 mv	
-113.5 dbm	150 mv	
-112.5 dbm	200 mv	
-110.5 dbm	300 mv	
-109 dbm	400 mv	
-108.5 dbm	500 mv	$Pi_{dbm} = -106.09 + 3.92 \ln (Vowt)$
-106 dbm	1.0 v	
-104.5 dbm	1.5 v	$r^2 = 1$
-103.5 dbm	2.0 v	
-103 dbm	2.5 v	
-102 dbm	3.0 v	
-101 dbm	3.5 v	
-100 dbm	5.0 v	
-99 dbm	6.0 v	
-98.5 dbm	7.0 v	
-97 dbm	8.0 v	
-91 dbm	9.0 v	$Pi_{dbm} = -157.6 + 29.5 \ln (Vowt)$
-90.5 dbm	10.0 v	$r^2 = .83$
-90 dbm	11.0 v	
-89.5 dbm	12.0 v	$Pi_{dbm} = -95.1 + .46 (Vowt)$
-89 dbm	13.15 v	$r^2 = 1$

TABLE 2.5.1

1.0 GHz/3GHz RECEIVER CALIBRATION DATA

Pi	Vo	
-146 dbm	10 mv	
-141 dbm	25 mv	
-136 dbm	40 mv	Pi = -118.02+5.75 ln (Vowt)
-131 dbm	70 mv	r^2=.99
-126 dbm	200 mv	
-121 dbm	.5 v	
-118 dbm	1.0 v	
-116 dbm	1.25 v	
-113.5 dbm	2.5 v	
-111 dbm	4.5 v	Pi = -117.48+1.36 (Vowt)
-108.5 dbm	8.0 v	r^2=.94
-106 dbm	9.0 v	
-102 dbm	10 v	

TABLE 2.5.2

3.0GHz/9.0GHz RECEIVER CALIBRATION DATA

Pi	Vo	
-139 dbm	50 mv	
-134 dbm	100 mv	
-129 dbm	300 mv	
-127 dbm	500 mv	
-125 dbm	800 mv	
-123 dbm	1.25 v	
-121 dbm	1.75 v	Pi= -116.32+4.98 ln (Vowt)
-119 dbm	2.5 v	
-117 dbm	4.0 v	
-115 dbm	6.0 v	
-113 dbm	8.5 v	
-111 dbm	8.5 v	
-109 dbm	9 v	
-107 dbm	10 v	
-105 dbm	11 v	
-103 dbm	12 v	

TABLE 2.5.3

SYSTEM PARAMATERS AT 737 MHz

Pi + A (Input Attinuation) - 30 db = P(Antenna) (dbw)

$P_R\ 10^{\frac{P(ant)}{10}}$ = Power out of Antenna in Watts

$$\sigma = \frac{(4\pi)^3 R^4 P_R}{Po\ Gt\ Gr\ \lambda^2} \qquad \text{(See Appendix)}$$

R = 4.42 Meters

Antenna Gain Ratio = 11.22 XMIT
Antenna Gain Ratio = 37.58 Receive

λ^2 = .0184 M^2

Po at 128 W/M^2 = 3162 Watts Pk.

TABLE 2.5.4

SYSTEM PARAMETERS AT 1 GHz

Pi + A (Input Attinuation) - 30 db = P (Antenna) (dbw)

$$P_R \; 10^{\frac{P(ANT)}{10}} = \text{Power out of Antenna in Watts}$$

$$\sigma = \frac{(4\pi)^3 R^4 P_R}{Po\, G_T\, G_R\, \lambda^2} \qquad \text{(See Appendix)}$$

R = 4.42 Meters
R_x Antenna Gain Ratio = 31.62
T_x Antenna Gain Ratio = 13.18
$\lambda^2 = 0.01$
Po AT 128 W/M^2 = 3162 W Pk

TABLE 2.5.5

SYSTEM PARAMETERS AT 3.0 GHz

Pi + A (Input Attinuation) - 30 db = P (Antenna) (dbw)

$P_R\ 10^{\frac{P(ANT)}{10}}$ = Power out of Antenna in Watts

$$\sigma = \frac{(4\pi)^3\ R^4\ P_R}{Po\ G_T\ G_R\ \lambda^2} \qquad \text{(See Appendix)}$$

R = 4.42 Meters

T_x Antenna Gain Ratio = 15.0

R_x Antenna Gain Ratio = 19.85

λ^2 .0011 M^2

Po at 128 W/M^2 = 10,000 W Pk

TABLE 2.5.6

3. DATA CONCLUSIONS.

3.1 Sources of Error.

Because of the highly random nature of harmonic conversion, it is difficult if not impossible to draw specific conclusions.

The sources for measurement error range from leakage from transmit to receive antennas, harmonic conversion of the chamber, harmonic leakage before or after the clean up filters, harmonic generation from junctions in the transmit path, standing wave patterns within the anachoic chamber, fundamental frequency overloading of the preamplifier front end, zero drift of the receiver detector, external man made interference signals, or radiated or conducted leakage from the transmitter room to the receiver room.

3.2 Data Interpretation.

Several possible sources of error exist as mentioned previously, so data manipulation is performed several different ways to achieve as much insight as possible into the signature measurements.

1. Least squares analysis is performed on four samples of each target at all power levels. These readings are somewhat awkwardly biased by the three lowest power levels, which usually represent the noise level, and variations which may exist between targets.

2. Least squares analysis is performed on the 128 W/M^2, 64 W/M^2, and 6.4 W/M^2 data. This prevents bias of the equation toward the noise level data.

3. To prevent ambiguities between individual targets, each sample is evaluated independently.

4. To minimize the effects of background sources, background runs are performed and subtracted from the averaged signature data. The results are equivalent to signal minus noise.

3.2 (Cont'd.)

In data analysis, abnormally large or small coefficients or exponents of P are assumed to be targets of extremely poor signature or significant error component.

These considerations have been taken into account in the following tabulations:

Frequency	Hand Grenade	Atom	AT/AV Mine	M-16
737 MHz	4×10^{-11}	3.16×10^{-10}	2×10^{-10}	1×10^{-12}
1.0 GHz	2×10^{-11}	6.76×10^{-11}	1.5×10^{-10}	5×10^{-11}
3.0 GHz	5×10^{-12}	4.17×10^{-12}	3.4×10^{-11}	2×10^{-11}

3.3 Ground Plane Data.

3.3.1 In most instances, the addition of a ground plane permitted a modest improvement in signature returns.

CUBIC CORPORATION
San Diego, California

FINAL REDUCED DATA

The following data represents the reduced radar cross section equation and signature.

Key

Example

737 MHz   HAND GRENADE   WITHOUT GROUND PLANE

WITH BACKGROUND SUBTRACTED

Transmit frequency

Target type

Target measured with or without groundplane installed

Signature measurements taken and computed. Background noise levels subtracted from the signature returns (Signal + noise - noise)

TARGET #   (PWR LEVELS)   EQUATION   SIGMA

Most target types consisted of four samples. Each sample was assigned a number by Cubic, i.e. 1234 signifies signature of samples 1 through 4 of hand grenade. Targets have been averaged together to form the data base.

This column represents the number of power levels taken to form the signature equation, i.e. "6" represents the equation was derived from the data taken at 128 W/meter, 64 W/sq. m, 6.4 W/sq. m, 0.64 W/sq. m., 0.064 W/sq. m, and 0.0064 W/sq. m.; "3" represents the equation was derived from data taken at 128 W/sq. m, 64 W/sq. m, 6.4 w/sq. m.

This is the signature equation as derived from a least squares analysis.

Sigma is the derived radar cross section at a normalized 1 W/sq meter.

3.4 Reduced Data

737 Mhz HAND GRENADE WTHOUT GROUND PLANE

TARGET #	(P LEVELS)	EQUATION	SIGMA
1 2 3 4	6	-9.99E 99 + 9.99E 99P↑ 0.00E 00	0.00E 00
1 2 3 4	3	-9.99E 99 + 9.99E 99P↑ 0.00E 00	0.00E 00
1	6	9.54E-05 +-9.54E-05P↑ 3.34E-06	2.59E-09
2	6	4.81E-04 +-4.81E-04P↑ 3.34E-06	5.04E-09
3	6	5.46E-04 +-5.46E-04P↑ 3.34E-06	5.70E-09
4	6	2.35E-04 +-2.35E-04P↑ 3.34E-06	2.46E-09
1	3	1.44E-09 +.1.29E-59P↑ 2.37E 01	1.44E-09
2	3	7.08E-11 +-1.24E-13P↑ 1.25E 00	7.07E-11
3	3	7.41E-11 +-2.79E-61P↑ 2.37E 01	7.41E-11
4	3	1.07E-11 + 3.18E-13P↑ 9.67E-01	1.10E-11

1 GHz HAND GRENADE WTHOUT GROUND PLANE

TARGET #	(P LEVELS)	EQUATION	SIGMA
1 2 3 4	6	-9.99E 99 + 9.99E 99P↑ 0.00E 00	0.00E 00
1 2 3 4	3	-9.99E 99 + 9.99E 99P↑ 0.00E 00	0.00E 00
1	6	5.44E-04 +-5.44E-04P↑ 3.34E-06	5.68E-09
2	6	5.55E-04 +-5.55E-04P↑ 3.34E-06	5.78E-09
3	6	3.19E-04 +-3.19E-04P↑ 3.34E-06	3.58E-09
4	6	9.94E-05 +-9.94E-05P↑ 3.34E-06	1.08E-09
1	3	-9.99E 99 + 9.99E 99P↑ 0.00E 00	0.00E 00
2	3	1.97E-11 +-2.45E-13P↑ 8.21E-01	1.95E-11
3	3	9.82E-12 + 3.09E-61P↑ 2.37E 01	9.82E-12
4	3	-9.99E 99 + 9.99E 99P↑ 0.00E 00	0.00E 00

3 GHz HAND GRENADE WTHOUT GROUND PLANE

TARGET #	(P LEVELS)	EQUATION	SIGMA
1 2 3 4	6	7.11E-12 +-2.16E-15P↑ 1.55E 00	7.11E-12
1 2 3 4	3	-9.99E 99 + 9.99E 99P↑ 0.00E 00	0.00E 00
1	6	2.71E-11 +-1.13E-14P↑ 1.59E .0	2.71E-11
2	6	2.28E-11 +-6.26E-15P↑ 1.66E 00	2.28E-11
3	6	2.83E-11 +-8.74E-15P↑ 1.66E 00	2.83E-11
4	6	1.47E-12 +-6.79E-63P↑ 2.37E 01	1.47E-12
1	3	-9.99E 99 + 9.99E 99P↑ 0.00E 00	0.00E 00
2	3	-9.99E 99 + 9.99E 99P↑ 0.00E 00	0.00E 00
3	3	-9.99E 99 + 9.99E 99P↑ 0.00E 00	0.00E 00
4	3	5.78E-12 +-3.03E-13P↑ 5.76E-01	5.48E-12

737 Mhz HAND GRENADE WTHOUT GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1 2 3 4	6	1.10E-10 + 7.51E-11P^ 3.83E-01	1.85E-10
1 2 3 4	3	4.11E-10 + 7.65E-60P^ 2.36E 01	4.11E-10
1	6	-3.70E-10 + 1.07E-09P^ 1.86E-01	7.02E-10
2	6	2.16E-05 +-2.16E-05P^ 3.34E-06	2.48E-10
3	6	5.61E-05 +-5.61E-05P^ 3.34E-06	6.11E-10
4	6	1.15E-05 +-1.15E-05P^ 3.34E-06	1.43E-10
1	3	1.47E-09 + 1.23E-59P^ 2.37E 01	1.47E-09
2	3	3.09E-11 +-3.05E-16P^ 2.36E 00	3.09E-11
3	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
4	3	7.89E-12 + 3.90E-15P^ 1.37E 00	7.89E-12

1 GHz HAND GRENADE WTHOUT GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1 2 3 4	6	2.94E-10 + 3.22E-59P^ 2.36E 01	2.94E-10
1 2 3 4	3	5.86E-10 + 4.00E-59P^ 2.36E 01	5.86E-10
1	6	8.66E-05 +-8.66E-05P^ 3.34E-06	9.02E-10
2	6	7.82E-05 +-7.82E-05P^ 3.34E-06	7.92E-10
3	6	1.14E-09 +-7.30E-10P^ 1.07E-01	4.08E-10
4	6	1.96E-05 +-1.96E-05P^ 3.34E-06	2.44E-10
1	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
2	3	2.30E-12 + 4.37E-66P^ 2.58E 01	2.30E-12
3	3	3.72E-13 + 5.38E-16P^ 2.24E 00	3.73E-13
4	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00

3 GHz HAND GRENADE WTHOUT GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1 2 3 4	6	4.06E-13 + 2.04E-33P^ 1.11E 01	4.06E-13
1 2 3 4	3	2.56E-14 + 1.39E-24P^ 6.44E 00	2.56E-14
1	6	-2.53E-13 + 3.87E-13P^ 1.54E-01	1.34E-13
2	6	-3.25E-13 + 5.34E-13P^ 1.95E-01	2.09E-13
3	6	-2.71E-12 + 3.24E-12P^ 5.24E-02	5.39E-13
4	6	-2.48E-13 + 3.77E-13P^ 1.51E-01	1.29E-13
1	3	6.61E-13 +-6.60E-63P^ 2.37E 01	6.61E-13
2	3	1.06E-12 +-8.22E-63P^ 2.37E 01	1.06E-12
3	3	2.02E-12 +-2.09E-62P^ 2.37E 01	2.02E-12
4	3	6.36E-13 +-6.44E-63P^ 2.37E 01	6.36E-13

737 Mhz ADAM WTHOUT GROUND PLANE

TARGET #	(P LEVELS)	EQUATION	SIGMA
1 2 3 4	6	1.64E-10 + 1.13E-16P^ 3.35E 00	1.64E-10
1 2 3 4	3	2.44E-10 + 5.05E-16P^ 3.47E 00	2.44E-10
1	6	2.38E-10 + 3.06E-14P^ 2.79E 00	2.38E-10
2	6	2.90E-05 +-2.90E-05P^ 3.34E-06	5.34E-10
3	6	4.99E-10 + 1.68E-11P^ 1.12E 00	5.16E-10
4	6	3.97E-10 + 5.93E-16P^ 3.35E 00	3.97E-10
1	3	1.21E-10 + 3.78E-14P^ 2.75E 00	1.21E-10
2	3	-2.87E-11 + 9.68E-12P^ 8.18E-01	-1.90E-11
3	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
4	3	1.67E-10 + 3.85E-15P^ 2.97E 00	1.67E-10

1 GHz ADAM WTHOUT GROUND PLANE

TARGET #	(P LEVELS)	EQUATION	SIGMA
1 2 3 4	6	9.85E-09 +-1.85E-62P^ 2.53E 01	9.85E-09
1 2 3 4	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
1	6	9.42E-05 +-9.41E-05P^ 1.62E-05	6.05E-09
2	6	6.06E-04 +-6.06E-04P^ 3.34E-06	7.68E-09
3	6	8.92E-05 +-8.92E-05P^ 3.34E-06	1.05E-09
4	6	-1.60E-11 + 1.51E-11P^ 8.42E-01	-9.45E-13
1	3	9.99E 99 +-9.99E 99P^ 0.00E 00	0.00E 00
2	3	-2.09E-11 + 5.70E-12P^ 1.31E 00	-1.52E-11
3	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
4	3	-1.82E-10 + 6.13E-11P^ 5.86E-01	-1.20E-10

3 GHz ADAM WTHOUT GROUND PLANE

TARGET #	(P LEVELS)	EQUATION	SIGMA
1 2 3 4	6	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
1 2 3 4	3	4.03E-10 +-5.38E-60P^ 2.36E 01	4.03E-10
1	6	-4.34E-10 + 7.23E-10P^ 2.19E-01	2.89E-10
2	6	1.05E-12 + 1.39E-14P^ 1.72E 00	1.07E-12
3	6	2.10E-12 + 2.94E-22P^ 5.22E 00	2.10E-12
4	6	9.15E-13 + 4.12E-17P^ 2.98E 00	9.15E-13
1	3	9.99E 99 +-9.99E 99P^ 0.00E 00	0.00E 00
2	3	4.65E-12 + 7.23E-15P^ 1.91E 00	4.66E-12
3	3	5.64E-12 + 2.69E-61P^ 2.37E 01	5.64E-12
4	3	3.68E-12 + 4.04E-18P^ 3.41E 00	3.68E-12

737 Mhz ADAM WIHOUT GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1 2 3 4	6	7.81E-11 + 1.50E-14P^ 2.75E 00	7.81E-11
1 2 3 4	3	2.04E-10 + 2.60E-14P^ 2.59E 00	2.04E-10
1	6	1.53E-10 + 1.93E-13P^ 2.41E 00	1.53E-10
2	6	2.51E-10 + 2.26E-60P^ 2.37E 01	2.51E-10
3	6	7.27E-11 + 7.70E-11P^ 8.29E-01	1.50E-10
4	6	1.40E-10 + 3.12E-14P^ 2.54E 00	1.40E-10
1	3	2.93E-10 + 1.59E-13P^ 2.45E 00	2.93E-10
2	3	-3.22E-13 + 9.74E-13P^ 1.27E 00	6.52E-13
3	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
4	3	2.08E-10 + 2.13E-14P^ 2.61E 00	2.08E-10

1 GHz ADAM WIHOUT GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1 2 3 4	6	1.06E-10 + 1.61E-15P^ 3.08E 00	1.06E-10
1 2 3 4	3	3.23E-10 + 1.11E-12P^ 1.42E 00	3.24E-10
1	6	3.73E-10 + 2.66E-11P^ 9.86E-01	3.99E-10
2	6	1.66E-09 + 1.64E-59P^ 2.37E 01	1.66E-09
3	6	5.17E-11 + 8.77E-12P^ 5.17E-01	6.05E-11
4	6	-1.65E-11 + 2.26E-11P^ 7.60E-01	6.16E-12
1	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
2	3	-8.31E-12 + 1.03E-11P^ 1.13E 00	2.53E-12
3	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
4	3	-2.39E-10 + 1.08E-10P^ 4.31E-01	-1.32E-10

3 GHz ADAM WIHOUT GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1 2 3 4	6	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
1 2 3 4	3	1.31E-10 + 5.08E-64P^ 2.56E 01	1.31E-10
1	6	-5.03E-10 + 3.31E-10P^ 1.98E-01	3.28E-10
2	6	1.07E-13 + 2.47E-14P^ 1.65E 00	1.31E-13
3	6	2.30E-14 + 6.77E-19P^ 3.61E 00	2.30E-14
4	6	1.05E-13 + 8.64E-17P^ 2.32E 00	1.05E-13
1	3	1.67E-09 +-1.27E-59P^ 2.37E 01	1.67E-09
2	3	4.37E-13 + 2.25E-14P^ 1.57E 00	5.19E-13
3	3	9.20E-14 + 5.51E-19P^ 3.65E 00	9.20E-14
4	3	4.25E-13 + 7.12E-17P^ 2.35E 00	4.25E-13

737 Mhz AT/AV MINE WIHOUT GROUND PLANE

TARGET #	(P LEVELS)	EQUATION	SIGMA
1 2 3 4	6	1.57E-09 + 5.60E-16P^ 3.50E 00	1.57E-09
1 2 3 4	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
1	6	2.60E-10 + 4.68E-63P^ 2.59E 01	2.60E-10
2	6	3.86E-09 + 1.68E-59P^ 2.37E 01	3.86E-09
3	6	1.10E-09 + 3.96E-59P^ 2.37E 01	1.10E-09
4	6	1.96E-09 +-7.91E-60P^ 2.37E 01	1.96E-09
1	3	4.52E-09 +-4.41E-59P^ 2.37E 01	4.52E-09
2	3	4.23E-09 + 1.30E-59P^ 2.37E 01	4.23E-09
3	3	7.97E-11 + 7.78E-19P^ 4.65E 00	7.97E-11
4	3	9.99E 99 +-9.99E 99P^ 0.00E 00	0.00E 00

1 GHz AT/AV MINE WIHOUT GROUND PLANE

TARGET #	(P LEVELS)	EQUATION	SIGMA
1 2 3 4	6	7.32E-10 + 2.26E-58P^ 2.35E 01	7.32E-10
1 2 3 4	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
1	6	1.35E-05 +-1.35E-05P^ 1.62E-05	6.64E-10
2	6	5.85E-05 +-5.85E-05P^ 3.34E-06	6.44E-10
3	6	4.75E-04 +-4.75E-04P^ 3.34E-06	4.92E-09
4	6	1.74E-04 +-1.74E-04P^ 3.34E-06	1.91E-09
1	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
2	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
3	3	3.66E-11 +-2.06E-61P^ 2.37E 01	3.66E-11
4	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00

3 GHz AT/AV MINE WIHOUT GROUND PLANE

TARGET #	(P LEVELS)	EQUATION	SIGMA
1 2 3 4	6	8.10E-12 + 1.14E-20P^ 5.20E 00	8.10E-12
1 2 3 4	3	8.84E-12 + 2.08E-14P^ 1.73E 00	8.86E-12
1	6	4.33E-12 + 7.36E-14P^ 1.70E 00	4.41E-12
2	6	2.08E-11 + 2.89E-14P^ 1.99E 00	2.08E-11
3	6	-3.78E-12 + 1.31E-11P^ 2.12E-01	9.30E-12
4	6	-2.44E-11 + 3.44E-11P^ 1.03E-01	9.94E-12
1	3	1.91E-11 + 2.43E-14P^ 1.92E 00	1.92E-11
2	3	8.65E-11 + 1.14E-16P^ 3.10E 00	8.65E-11
3	3	2.72E-11 + 2.00E-61P^ 2.37E 01	2.72E-11
4	3	3.54E-11 +-2.34E-61P^ 2.37E 01	3.54E-11

737 Mhz AT/AV MINE WTHOUT GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1 2 3 4	6	8.68E-10 + 4.41E-14P^ 2.57E 00	8.69E-10
1 2 3 4	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
1	6	2.20E-09 +-2.00E-59P^ 2.37E 01	2.20E-09
2	6	-1.30E-04 + 1.30E-04P^ 3.34E-06	3.46E-09
3	6	1.90E-10 + 1.21E-17P^ 4.08E 00	1.90E-10
4	6	6.15E-10 + 1.23E-10P^ 5.00E-01	7.38E-10
1	3	4.68E-09 +-4.60E-59P^ 2.37E 01	4.68E-09
2	3	4.42E-09 + 1.09E-59P^ 2.37E 01	4.42E-09
3	3	9.23E-11 + 3.67E-17P^ 3.68E 00	9.23E-11
4	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00

1 GHz AT/AV MINE WTHOUT GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1 2 3 4	6	1.51E-10 + 5.81E-59P^ 2.36E 01	1.51E-10
1 2 3 4	3	1.07E-10 + 6.07E-60P^ 2.36E 01	1.07E-10
1	6	1.08E-05 +-1.08E-05P^ 3.34E-06	1.53E-10
2	6	1.27E-05 +-1.27E-05P^ 3.34E-06	1.73E-10
3	6	3.08E-10 +-1.70E-10P^ 1.21E-01	1.38E-10
4	6	3.16E-10 +-1.34E-10P^ 1.72E-01	1.82E-10
1	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
2	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
3	3	3.32E-11 +-1.83E-61P^ 2.37E 01	3.32E-11
4	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00

3 GHz AT/AV MINE WTHOUT GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1 2 3 4	6	5.70E-12 + 2.09E-20P^ 5.08E 00	5.70E-12
1 2 3 4	3	-5.39E-14 + 1.26E-13P^ 1.37E 00	7.16E-14
1	6	2.97E-13 + 1.50E-13P^ 1.56E 00	4.47E-13
2	6	1.29E-11 + 9.96E-14P^ 1.74E 00	1.30E-11
3	6	-3.79E-13 + 4.18E-13P^ 9.58E-01	3.90E-14
4	6	-7.31E-12 + 1.23E-11P^ 2.13E-01	5.03E-12
1	3	1.48E-12 + 1.40E-13P^ 1.57E 00	1.62E-12
2	3	5.60E-11 + 9.79E-15P^ 2.19E 00	5.60E-11
3	3	-2.56E-12 + 7.14E-13P^ 3.57E-01	-1.85E-12
4	3	2.61E-11 +-1.75E-61P^ 2.37E 01	2.61E-11

737 Mhz M-16 MINE WTHOUT GROUND PLANE

TARGET #	(P LEVELS)	EQUATION	SIGMA
1 2 3 4	6	1.09E-08 +-2.17E-62P^ 2.53E 01	1.09E-08
1 2 3 4	3	3.88E-10 + 5.14E-59P^ 2.36E 01	3.88E-10
1	6	5.35E-05 +-5.35E-05P^ 3.34E-06	6.03E-10
2	6	4.63E-05 +-4.63E-05P^ 3.34E-06	4.93E-10
3	6	1.08E-04 +-1.08E-04P^ 3.34E-06	1.45E-09
4	6	4.02E-04 +-4.02E-04P^ 3.34E-06	4.16E-09
1	3	3.21E-12 + 9.04E-16P^ 2.37E 00	3.21E-12
2	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
3	3	-2.25E-11 + 3.49E-12P^ 1.12E 00	-1.90E-11
4	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00

1 GHz M-16 MINE WTHOUT GROUND PLANE

TARGET #	(P LEVELS)	EQUATION	SIGMA
1 2 3 4	6	3.73E-09 +-7.32E-63P^ 2.58E 01	3.73E-09
1 2 3 4	3	5.93E-10 + 4.06E-59P^ 2.36E 01	5.93E-10
1	6	8.77E-05 +-8.77E-05P^ 3.34E-06	9.23E-10
2	6	1.00E-04 +-1.00E-04P^ 3.34E-06	1.04E-09
3	6	1.06E-04 +-1.06E-04P^ 3.34E-06	1.10E-09
4	6	1.10E-04 +-1.10E-04P^ 3.34E-06	1.14E-09
1	3	3.35E-11 +-3.23E-61P^ 2.37E 01	3.35E-11
2	3	9.99E 99 +-9.99E 99P^ 0.00E 00	0.00E 00
3	3	3.00E-12 + 8.95E-68P^ 2.53E 01	3.00E-12
4	3	3.18E-12 + 1.58E-61P^ 2.37E 01	3.18E-12

3 GHz M-16 MINE WTHOUT GROUND PLANE

TARGET #	(P LEVELS)	EQUATION	SIGMA
1 2 3 4	6	5.11E-12 + 4.16E-60P^ 2.35E 01	5.11E-12
1 2 3 4	3	2.36E-12 + 4.20E-61P^ 2.36E 01	2.36E-12
1	6	-8.93E-08 + 8.93E-08P^ 3.34E-06	1.68E-12
2	6	8.61E-13 +-4.19E-63P^ 2.37E 01	8.61E-13
3	6	-3.18E-11 + 3.30E-11P^ 1.02E-02	1.28E-12
4	6	-1.21E-07 + 1.21E-07P^ 3.34E-06	1.97E-12
1	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
2	3	3.21E-12 +-1.10E-13P^ 6.64E-01	3.10E-12
3	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
4	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00

737 Mhz M-16 MINE WITHOUT GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1 2 3 4	6	7.83E-09 +-1.63E-62P^ 2.58E 01	7.83E-09
1 2 3 4	3	1.93E-11 + 1.54E-26P^ 8.03E 00	1.93E-11
1	6	2.84E-11 + 4.23E-61P^ 2.37E 01	2.84E-11
2	6	9.10E-06 +-9.10E-06P^ 3.34E-06	1.02E-10
3	6	4.00E-10 + 4.39E-60P^ 2.37E 01	4.00E-10
4	6	1.39E-04 +-1.39E-04P^ 3.34E-06	1.90E-09
1	3	2.24E-13 + 9.63E-19P^ 3.73E 00	2.24E-13
2	3	5.71E-12 + 1.59E-62P^ 2.37E 01	5.71E-12
3	3	-2.29E-11 + 5.87E-12P^ 1.01E 00	-1.70E-11
4	3	1.83E-11 +-1.90E-61P^ 2.37E 01	1.83E-11

1 GHz M-16 MINE WITHOUT GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1 2 3 4	6	8.24E-10 +-1.69E-63P^ 2.58E 01	8.24E-10
1 2 3 4	3	1.06E-10 + 2.38E-60P^ 2.36E 01	1.06E-10
1	6	1.45E-05 +-1.45E-05P^ 3.34E-06	1.63E-10
2	6	1.44E-05 +-1.44E-05P^ 3.34E-06	1.45E-10
3	6	1.22E-10 +-7.13E-11P^ 1.32E-01	5.[illegible]6E-11
4	6	1.10E-10 +-6.55E-11P^ 1.22E-01	4.[illegible]7E-11
1	3	3.16E-11 +-3.27E-61P^ 2.37E 01	3.16E-11
2	3	0.00E 00 + 0.00E 00P^ 1.50E 00	0.00E 00
3	3	0.00E 00 + 0.00E 00P^ 1.00E 00	0.00E 00
4	3	1.07E-14 + 1.00E-21P^ 4.65E 00	1.07E-14

3 GHz M-16 MINE WITHOUT GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1 2 3 4	6	3.17E-12 + 3.64E-60P^ 2.35E 01	3.17E-12
1 2 3 4	3	2.02E-14 + 3.28E-22P^ 5.07E 00	2.02E-14
1	6	8.26E-17 + 3.88E-23P^ 4.60E 00	8.26E-17
2	6	0.00E 00 + 0.00E 00P^ 1.50E 00	0.00E 00
3	6	-3.30E-14 + 5.03E-14P^ 6.39E-01	1.73E-14
4	6	-1.19E-13 + 2.09E-13P^ 4.94E-01	9.00E-14
1	3	3.31E-16 + 3.12E-23P^ 4.55E 00	3.31E-16
2	3	0.00E 00 + 0.00E 00P^ 1.50E 00	0.00E 00
3	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00
4	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00

737 Mhz ADAM WITH GROUND PLANE

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1	6	4.54E-10 + 4.39E-10P^ 1.03E 00	8.93E-10
1	3	-4.80E-09 + 1.04E-09P^ 8.71E-01	-3.76E-09

1 GHz ADAM WITH GROUND PLANE

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1	6	4.18E-06 +-4.18E-06P^ 1.62E-05	2.74E-10
1	3	1.90E-12 + 1.18E-19P^ 4.43E 00	1.90E-12

3 GHz ADAM WITH GROUND PLANE

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1	6	-3.98E-11 + 7.84E-11P^ 2.61E-01	3.86E-11
1	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00

737 Mhz AT/AV MINE WITH GROUND PLANE

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1	6	4.62E-09 +-8.97E-59P^ 2.35E 01	4.62E-09
1	3	9.99E 99 +-9.99E 99P^ 0.00E 00	0.00E 00

1 GHz AT/AV MINE WITH GROUND PLANE

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1	6	2.31E-05 +-2.31E-05P^ 3.34E-06	3.40E-10
1	3	7.13E-12 + 4.19E-13P^ 1.29E 00	7.55E-12

3 GHz AT/AV MINE WITH GROUND PLANE

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1	6	2.95E-13 + 4.05E-17P^ 2.93E 00	2.95E-13
1	3	1.19E-12 + 1.95E-17P^ 3.08E 00	1.19E-12

737 Mhz ADAM WITH GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1	6	-5.61E-10 + 3.79E-10P^ 3.94E-01	3.13E-10
1	3	-5.23E-09 + 1.73E-09P^ 7.67E-01	-3.50E-09

1 GHz ADAM WITH GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1	6	2.52E-10 +-1.96E-64P^ 2.59E 01	2.52E-10
1	3	2.22E-12 + 4.03E-18P^ 3.70E 00	2.22E-12

3 GHz ADAM WITH GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1	6	-3.60E-11 + 7.11E-11P^ 2.76E-01	3.51E-11
1	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00

737 Mhz AT/AV MINE WITH GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1	6	2.04E-09 + 4.82E-11P^ 6.23E-01	2.09E-09
1	3	-9.99E 99 + 9.99E 99P^ 0.00E 00	0.00E 00

1 GHz AT/AV MINE WITH GROUND PLANE
WITH BACKGROUND SUBTRACTED

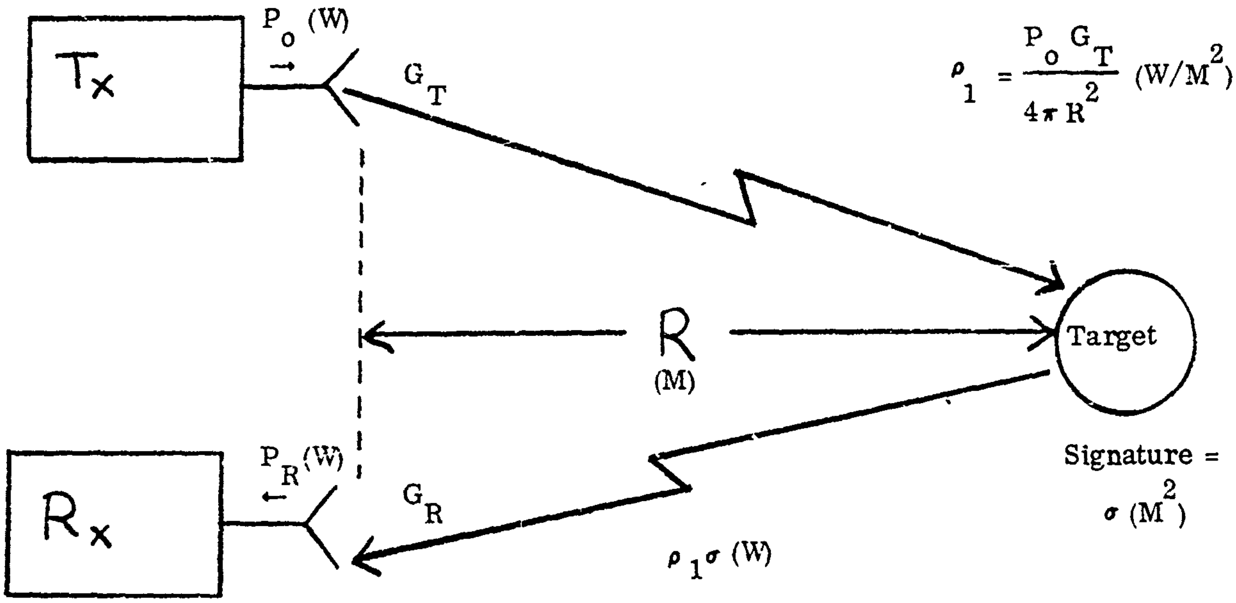
TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1	6	2.10E-11 + 2.60E-13P^ 1.37E 00	2.13E-11
1	3	8.56E-12 + 6.10E-13P^ 1.21E 00	9.17E-12

3 GHz AT/AV MINE WITH GROUND PLANE
WITH BACKGROUND SUBTRACTED

TARGET #	(PWR LEVELS)	EQUATION	SIGMA
1	6	8.05E-14 + 4.59E-17P^ 2.90E 00	8.06E-14
1	3	3.22E-13 + 3.79E-17P^ 2.94E 00	3.23E-13

APPENDIX 1

SIGNATURE EQUATION DERIVATION



$$\rho_2 = \frac{\rho_1}{4\pi R^2} \ (W/M^2)$$

$$\rho_2 = \frac{P_o G_T \sigma}{(4\pi)^2 R^4} \ (W/M^2) \qquad (1)$$

$$P_R = \rho_2 A \ (W) \qquad (2)$$

where A is receiver antenna aperture

$$A = \frac{\lambda^2 G_R}{4\pi} \ (M^2) \qquad (3)$$

From (2) and (3).

$$P_R = \frac{P_o G_T G_R \lambda^2 \sigma}{(4\pi)^3 R^4}$$

Solving for σ:

$$\sigma = \frac{(4\pi)^3 R^4}{G_T G_R \lambda^2} \cdot \frac{P_R}{P_o}$$

Where:

R	=	Distance from antenna to target in meters.
P_R	=	Power at receiver input in peak watts.
P_o	=	Transmitter power output at antenna terminal in peak watts.
G_T	=	Transmitter antenna gain $G_T = 10^{\frac{\text{Gain (dB)}}{10}}$
G_R	=	Receiver antenna gain $G_R = 10^{\frac{\text{Gain (dB)}}{10}}$
λ	=	Receive frequency wavelength in meters.
σ	=	Effective signature in sq. meters.

APPENDIX 2

COMPUTER PROGRAM LISTINGS

```
********************************
*                              *
*                              *
*                              *
*                              *
*    DATA AQUISITION PROGRAM   *
*                              *
*                              *
*                              *
*                              *
********************************
```

```
0: [illegible]
1: dim H$[3,80],[illegible],H[32,2]
2: dim D$[15,[illegible]],X$[1C,10],C$[3,80]
3: dim E$[20],F$[illegible]$[10],[illegible][27]
4: gto "go"
5: "PAD":
6: wtb 712,"A2E3456"
7: wtb 712,X$[W];wait 50;wtb 712,"B2";wait 2000
8: wtb 712,"-UNL"
9: ret
10: "REC":
11: ent "any additional comments?",D$[3*r6,1]
12: if flg1;gto "nfl"
13: rcf J,D$,B$,D[*]
14: gto "ret"
15: "nfl":trk r5;ldf 0,H[*]
16: for I=17 to 32
17: if H[I,2]=0;jmp 2
18: next I
19: J→H[I,2]
20: 1→H[J,2]
21: trk r5;rcf 0,H[*]
22: for M=1 to 3
23: D$[M*r6]→H$[M]
24: B$[M*r6]→I$[M]
25: next M
26: rcf I,H$,I$,D[*]
27: "ret":ret
28: "ZAP":dsp "TRANSMITTER POWER IS DOWN"
29: stp
30: ret
31: "go":" "→C$[1]→C$[2]→C$[3]
32: cfg 1
33: sfg 2
34: ent "Target Type",E$
35: len(E$)→E
36: E$→C$[1,1]
37: " "→C$[1,E+1,19]
38: ent "Target Code",A$
39: if A$=" ";jmp -1
40: if num(A$)<65;jmp -2
41: if num(A$)>68;jmp -3
42: A$→C$[1,20]
43: ent "Target Number",E$
44: if val(E$)>4;jmp -1
45: val(E$)→r4
46: len(E$)→E
47: E$→C$[1,21]
48: " "→C$[1,E+21,24]
```

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```
53: ent "last Personal",E$
54: len(E$)→E
55: E$→C$[1,46]
56: " "→C$[1,E+46,66]
57: ent "Gnd plane--type with or without",E$
58: if E$="with";1→r5;jmp 3
59: if E$="without";0→r5;jmp 2
    jmp -3
    E$→C$[1,67]
    len(E$)→E
    "G/P"→C$[1,E+67]
    trk 1,5
    4*(num(A$)-65)+r4→J
    wrt 6,C$[1];wrt 6
    ent "Entry errors to correct?--yes/no",G$
    if G$="no";jmp 3
    if G$="yes";gto "go"
    jmp -3
    fmt 2,f4.0
    ldf J,D$,B$,D[*]
    wrt 6.2,"YOU HAVE ACCESSED FILE #",J,"WHICH HAS THE FOLLOWING HEADING:
    wrt 6
    for I=1 to 5
    wrt 6,D$[3I-2];wrt 6,D$[3*I-1];wrt 6,D$[3*I];wrt 6
    wrt 6,B$[3I-2];wrt 6,B$[3I-1];wrt 6,B$[3*I];wrt 6
    if D$[3I-2]=" ";gto "com"
    next I
    "com":I→r6;C$[1]→D$[r6+2*(r6-1)]
    ent "enter comments for current run",D$[3*r6-1,1]
    wrt 6,"THE CURRENT DATA WILL HAVE THE FOLLOWING HEADING:"
    wrt 6
    wrt 6,D$[3*r6-2];wrt 6,D$[3*r6-1];wrt 6,D$[3*r6];wrt 6;wrt 6
    "HHHNNNH"→B$[3*r6-2]→B$[3*r6-1]→B$[3*r6]
    " "→F$
    "CUT":" "→F$;ent "Plane of Cut(ie x-y,y-z,z-x)",F$
    if F$="x-y";1→G;gto "PWR"
    if F$="y-z";2→G;gto "PWR"
    if F$="z-x";3→G;gto "PWR"
    dsp "reenter desired cut";wait 2000;gto "CUT"
    "PWR":dsp "set generator power level";stp
    ent "Target Power Density",P
    if P=128;1→H;jmp 2
    int(2-log(P/64))→H
    " "→G$
    ent "any Pwr/cut entry errors?",G$
```

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```
103: next I
104: " "→G$
105: if flg2;jmp 6
106: beep;wait 500;beep;wait 500;beep
107: ent "power/cut repeat-wish to redo?",G$
108: if G$="no";cfg 1;sfg 2;jmp 3
109: if G$="yes";sfg 2;gto "CUT"
110: jmp -3
111: "Y"→B$[3*r6+G-3,H,H]
112: gto "two"
113: "two":wtb 712,"B123456"
114: "A0"→X$[1]
115: "A6"→X$[2]
116: "A5"→X$[3]
117: "A56"→X$[4]
118: "A4"→X$[5]
119: "A46"→X$[6]
120: "A45"→X$[7]
121: "A456"→X$[8]
122: "A34"→X$[9]
123: "A346"→X$[10]
124: "A345"→X$[11]
125: "A3456"→X$[12]
126: fmt 1,f8,2f8.3
127: rem 712;rem 723
128: fmt 3,f10.4
129: wrt 6,F$,"cut"
130: wrt 6.3,P,"watts/sq meter"
131: wrt 6
132: wrt 6,"   deg      volts     dB"
133: wtb 6
134: for N=1 to 8
135: wtb 723,"-UNL"
136: wtb 712,"B3456"
137: wtb 712,"-UNL"
138: 1→Q
139: "start":0→S
140: dsp "transient check"
141: "one":trg 723;red 723,r1,B;wait 1000
142: trg 723;red 723,r2,B
143: if abs(r1-r2)>.05*r1;gto "one"
144: dsp " "
145: for M=1 to 25
146: dsp "reading voltage"
147: trg 723;red 723,R[M],S;wtb 723,"-UNT"
148: if M>20;jmp 2
```

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```
154: gto "start"
155: trg 723;red 723,X,B;wtb 723,"-UHT"
156: if X>A;jmp 3
157: wtb "ZAP"
158: gto "start"
159: if Q=12;jmp 5
160: if S/20<12;jmp 4
161: Q+1→Q
162: gsb "PAD"
163: gto "start"
164: S/20→D[G,H,N,1];10*(Q-1)→D[G,H,N,2]
165: wrt 6.1,45(N-1),D[G,H,N,1],D[G,H,N,2]
166: dsp "pedestal rotating"
167: wtb 712,"A1";wait 300;wtb 712,"B1";wait 3000
168: dsp " "
169: next N
170: wrt 6
171: " "→G$
172: wrt 6
173: ent "new target?--key in yes or no",G$
174: if G$="no";jmp 5
175: if G$="yes";jmp 2
176: jmp -3
177: gsb "REC"
178: gto "END"
179: " "→G$
180: ent "new cut or power?--key yes or no",G$
181: if G$="yes";gto "CUT"
182: if G$="no";jmp 2
183: jmp -3
184: gsb "REC"
```

RAW DATA REDUCTION

PROGRAMS

```
0: "737 Mhz RAW DATA REDUCTION PROGRAM":
1: "COMPUTES AND PRINTS SIGNATURE IN sqM AND STORES ON SIGNATURE DATA TAPE":
2: ent "WHICH TRACK ON RAW DATA TAPE",B;if B>1;gto -0
3: trk B
4: ent "WHICH FILE???",F
5: dim A$[15,80],B$[15,8],D[3,6,8,2],Q[3,6,8]
6: sfg 14
7: dsp "COMPUTING DATA"
8: ldf F,A$,B$,D[*]
9: 1→L;1→M;1→N
10: if D[L,M,N,1]<=7;-106.09+3.92ln(D[L,M,N,1])→R
11: if D[L,M,N,1]>7;if D[L,M,N,1]<=10;-157.6+29.5ln(D[L,M,N,1])→R
12: if D[L,M,N,1]>10;-95.1+.46D[L,M,N,1]→R
13: D[L,M,N,2]→D
14: R+D-30→P
15: tn^(P/10)→Q
16: (4π)^3*4.42^4→K
17: 11.22*37.58*.0184→Y
18: K/Y→C
19: if M=1;3162→X
20: if M=2;1581→X
21: if M=3;158.1→X
22: if M=4;15.81→X
23: if M=5;1.581→X
24: if M=6;.1581→X
25: C*Q/X→Q[L,M,N]
26: dsp P;dsp "P=",P
27: if L>2;gto 30
28: L+1→L
29: gto 10
30: 1→L
31: if M>5;gto 34
32: M+1→M
33: gto 10
34: 1→L;1→M
35: if N>7;gto 40
36: N+1→N
37: gto 10
38:
39:
40: wrt 6,"FILE",F*1
41: wrt 6,A$[1]
42: 1→M;1→N;0→A
43: fmt 1,2/,5x,"737 Mhz--128 W/sqM  RADAR XSECTION IN sqM=";if M=1;wrt 6.1
44: fmt 2,2/,5x,"737 Mhz--64 W/sqM  RADAR XSECTION IN sqM=";if M=2;wrt 6.2
*11608
```

```
44: fmt 2,2/,5x,"737 Mnz--64 W/sqM  RADAR XSECTION IN sqM=";if M=2;wrt 6.2
45: fmt 3,2/,5x,"737 Mnz--6.4 W/sqM  RADAR XSECTION IN sqM=";if M=3;wrt 6.3
46: fmt 4,2/,5x,"737 Mnz--.64 W/sqM  RADAR XSECTION IN sqM=";if M=4;wrt 6.4
47: fmt 5,2/,5x,"737 Mnz--.064 W/sqM  RADAR XSECTION IN sqM=";if M=5;wrt 6.5
48: fmt 6,2/,5x,"737 Mnz--.0064 W/sqM  RADAR XSECTION IN sqM=";if M=6;wrt 6.6
49: fmt 7,5x,"ANGLE",12x,"X-Y",14x,"Y-Z",12x,"Z-X",/;wrt 6.7
50: fmt 8,5x,f3.0,10x,e10.2,7x,e10.2,5x,e10.2
51: wrt 6.8,A,Q[1,M,N],Q[2,M,N],Q[3,M,N]
52: A+45→A;N+1→N
53: if N>8;gto 55
54: gto 51
55: M+1→M;0→A;1→N
56: if M>6;gto 58
57: gto 43
58: dsp "INSERT 737 MHz SIGNATURE TAPE";stp
59: ent "STORE ON WHICH TRACK??",B;if B>1;gto -0
60: trk B
61: ent "STORE IN WHICH FILE??",Z
62: fdf Z
63: rcf Z,A$,B$,D[*],Q[*]
64: fmt 9,5x,"THE ABOVE DATA IS IN FILE #",1x,f2.0,5x,"ON TRACK #",1x,f2.0
65: wrt 6.9,Z,B;wrt 6;wrt 6
66: "END":dsp "INSERT 737 MHz RAW DATA TAPE";end
*7353
```

```
0: "1 Ghz RAW DATA REDUCTION PROGRAM":
1: "COMPUTES AND PRINTS SIGNATURE IN sqM AND STORES ON SIGNATURE DATA TAPE":
2: ent "WHICH TRACK ON RAW DATA TAPE",B;if B>1;gto -0
3: trk B
4: ent "WHICH FILE???",F
5: dim A$[15,80],B$[15,6],D[3,6,8,2],Q[3,6,8]
6: sfg 14
7: dsp "COMPUTING DATA"
8: ldf F,A$,B$,D[*]
9: 1→L;1→M;1→N
10: if D[L,M,N,1]<=1;gto "LOG"
11: -116.32+1.15*D[L,M,N,1]→R;gto 13
12: "LOG":-116.72+6.19*ln(D[L,M,N,1])→R
13: D[L,M,N,2]→D
14: R+D-30→P
15: tn^(P/10)→Q
16: (4π)^3*4.42^4→K
17: 31.62*13.18*.01→Y
18: K/Y→C
19: if M=1;3162→X
20: if M=2;1581→X
21: if M=3;158.1→X
22: if M=4;15.81→X
23: if M=5;1.581→X
24: if M=6;.1581→X
25: C*Q/X→Q[L,M,N]
26: dsp P;dsp "P=",P
27: if L>2;gto 30
28: L+1→L
29: gto 10
30: 1→L
31: if M>5;gto 34
32: M+1→M
33: gto 10
34: 1→L;1→M
35: if N>7;gto 40
36: N+1→N
37: gto 10
38:
39:
40: wrt 6,"FILE",F*1
41: wrt 6,A$[1]
42: 1→M;1→N;0→A
43: fmt 1,2/,5x,"1.0 Ghz--123 w/sqM  RADAR XSECTION IN sqM=";if M=1;wrt 6.1
44: fmt 2,2/,5x,"1.0 Ghz--64 W/sqM  RADAR XSECTION IN sqM=";if M=2;wrt 6.2
45: fmt 3,2/,5x,"1.0 Ghz--6.4 W/sqM  RADAR XSECTION IN sqM=";if M=3;wrt 6.3
*30295
```

```
45: fmt 3,2/,5x,"1.0 Ghz--6.4 W/sqM  RADAR XSECTION IN sqM=";if M=3;wrt 6.3
46: fmt 4,2/,5x,"1.0 Ghz--.64 W/sqM  RADAR XSECTION IN sqM=";if M=4;wrt 6.4
47: fmt 5,2/,5x,"1.0 Ghz--.064 W/sqM  RADAR XSECTION IN sqM=";if M=5;wrt 6.5
48: fmt 6,2/,5x,"1.0 Ghz--.0064 W/sqM  RADAR XSECTION IN sqM=";if M=6;wrt 6.6
49: fmt 7,5x,"ANGLE",12x,"X-Y",14x,"Y-Z",12x,"Z-X",/;wrt 6.7
50: fmt 8,5x,f3.0,10x,e10.2,7x,e10.2,5x,e10.2
51: wrt 6.8,A,Q[1,M,N],Q[2,M,N],Q[3,M,N]
52: A+45→A;N+1→N
53: if N>8;gto 55
54: gto 51
55: M+1→M;0→A;1→N
56: if M>6;gto 58
57: gto 43
58: dsp "INSERT 1 GHz SIGNATURE TAPE";stp
59: ent "STORE ON WHICH TRACK",Y;if Y>1;gto -0
60: trk Y
61: ent "STORE IN WHICH FILE",Z
62: fdf Z
63: rcf Z,A$,B$,D[*],Q[*]
64: fmt 9,5x,"THE ABOVE DATA IS IN FILE #",1x,f2.0,5x,"ON TRACK #",1x,f2.0
65: wrt 6.9,Z,Y;wrt 6;wrt 6
66: "END":dsp "INSERT 1 GHz RAW DATA TAPE";end
*12984
```

```
0: "3 Ghz RAW DATA REDUCTION PROGRAM":
1: "COMPUTES AND PRINTS SIGNATURE IN sqM AND STORES ON SIGNATURE DATA TAPE":
2: ent "WHICH TRACK ON RAW DATA TAPE ??",B;if B>1;gto -0
3: trk B
4: ent "WHICH FILE ???",F
5: dim A$[15,80],B$[15,6],D[3,6,8,2],Q[3,6,8]
6: sfg 14
7: dsp "COMPUTING DATA"
8: ldf F,A$,B$,D[*]
9: 1→L;1→M;1→N;1→O
10: -116.32+4.98*ln(D[L,M,N,1])→R
11: D[L,M,N,2]→D
12: R+D-30→P
13: tn^(P/10)→Q
14: (4π)^3*4.42^4→K
15: 15*19.85*.0011→Y
16: K/Y→C
17: if M=1;10000→X
18: if M=2;5000→X
19: if M=3;500→X
20: if M=4;50→X
21: if M=5;5→X
22: if M=6;.5→X
23: Q*C/X→Q[L,M,N]
24: dsp P;dsp "P=",P
25: if L>2;gto 28
26: L+1→L
27: gto 10
28: 1→L
29: if M>5;gto 32
30: M+1→M
31: gto 10
32: 1→L;1→M
33: if N>7;gto 38
34: N+1→N
35: gto 10
36:
37:
38: wrt 6,"FILE",F*1
39: wrt 6,A$[1]
40: 1→M;1→N;0→A
41: fmt 1,2/,5x,"3.0 Ghz--128 W/sqM  RADAR XSECTION IN sqM=";if M=1;wrt 6.1
42: fmt 2,2/,5x,"3.0 Ghz--64 W/sqM  RADAR XSECTION IN sqM=";if M=2;wrt 6.2
43: fmt 3,2/,5x,"3.0 Ghz--6.4 W/sqM  RADAR XSECTION IN sqM=";if M=3;wrt 6.3
44: fmt 4,2/,5x,"3.0 Ghz--.64 W/sqM  RADAR XSECTION IN sqM=";if M=4;wrt 6.4
45: fmt 5,2/,5x,"3.0 Ghz--.064 W/sqM  RADAR XSECTION IN sqM=";if M=5;wrt 6.5
*21213
```

```
46: fmt 6,2/,5x,"3.0 Ghz--.0064 W/sqM  RADAR XSECTION IN sqM=";if N=6;wrt 6.6
47: fmt 7,5x,"ANGLE",12x,"X-Y",14x,"Y-Z",12x,"Z-X",/;wrt 6.7
48: fmt 8,5x,f3.0,10x,e10.2,7x,e10.2,5x,e10.2
49: wrt 6.8,A,Q[1,M,N],Q[2,M,N],Q[3,M,N]
50: A+45→A;N+1→N
51: if N>8;gto 53
52: gto 49
53: M+1→M;0→A;1→N
54: if M>6;gto 56
55: gto 41
56: dsp "INSERT 3 GHz SIGNATURE TAPE";stp
57: ent "STORE ON WHICH TRACK ???",B;if B>1;gto -0
58: trk B
59: ent "STORE IN WHICH FILE ??",Z
60: fdf Z
61: rcf Z,A$,B$,D[*],Q[*]
62: fmt 9,5x,"THE ABOVE DATA IS IN FILE #",1x,f2.0,5x,"ON TRACK #",1x,f2.0
63: wrt 6.9,Z,B;wrt 6;wrt 6
64: "END":dsp "INSERT 3 GHz RAW DATA TAPE";end
*824
```

BACKGROUND PROCESSING

PROGRAMS

```
0: "737 Mhz BACKGROUND AVEREGING PGM.":
1: "AVEREGES BACKGROUND DATA FOR USE IN FINAL COMPUTATIONS":
2: flt 2
3:
4: ent "FILE ASSOCIATED WITH",A
5: dim D[3,6,8,2];0→P;0→F;0→V;0→M;0→D;0→G
6: ent "IRRADIATION INT.,1-6;1=123 etc...",M
7: ent "VOLTAGE OUTPUT?,ENTER Vo",V
8: sfg 14
9: if V<=7;-106.09+3.92ln(V)→R
10: if V>7;if V<=10;-157.6+29.5ln(V)→R
11: if V>10;-95.1+.46V→R
12: ent "PAD SETTING?,ENTER PAD",D
13: R+D-30→P
14: tn^(P/10)→Q
15: (4π)^3*4.42^4→K
16: 11.22*37.58*.0184→Y
17: K/Y→C
18: if M=1;3162→X
19: if M=2;1581→X
20: if M=3;158.1→X
21: if M=4;15.81→X
22: if M=5;1.581→X
23: if M=6;.1581→X
24: C*Q/X+S→S
25: G+1→G;0→T;ent "FINISHED??,ENT 1",T
26: if T#1;gto 7
27: if T=1;S/G→D[1,M,8,2];0→G;0→S
28: if M=6;gto "LIST"
29: if M#6;gto 6
30: "LIST":dsp "TO LIST ON PRINTER PRESS CONT."
31: stp
32: prt "FILE #",A;spc 2
33: for N=1 to 6
34: prt D[1,N,8,2];spc 3
35: next N
36: end
*3341
```

```
0: "1Ghz BACKGROUND AVEREGING PROGRAM":
1: "AVEREGES BACKGROUND DATA FOR USE IN FINAL COMPUTATIONS":
2: flt 2
3:
4: ent "FILE ASSOCIATED WITH",A
5: dim D[3,6,8,2];0→P;0→F;0→V;0→M;0→D;0→G
6: ent "IRRADIATION INT.,1-6;1=128 etc...",M
7: ent "VOLTAGE OUTPUT?,ENTER Vo",V
8: sfg 14
9: if V<=1;gto "LOG"
10: -116.82+1.15*V→R;gto 12
11: "LOG":-116.72+6.19*ln(V)→R
12: ent "PAD SETTING?,ENTER PAD",D
13: R+D-30→P
14: tn^(P/10)→Q
15: (4π)^3*4.42^4→K
16: 31.62*13.18*.01→Y
17: K/Y→C
18: if M=1;3162→X
19: if M=2;1581→X
20: if M=3;158.1→X
21: if M=4;15.81→X
22: if M=5;1.581→X
23: if M=6;.1581→X
24: C*Q/X+S→S
25: G+1→G;0→T;ent "FINISHED??,ENT 1",T
26: if T#1;gto 7
27: if T=1;S/G→D[1,M,8,2];0→G;0→S
28: if M=6;gto "LIST"
29: if M#6;gto 6
30: "LIST":dsp "TO LIST ON PRINTER PRESS CONT."
31: stp
32: prt "FILE #",A;spc 2
33: for N=1 to 6
34: prt D[1,N,8,2];spc 3
35: next N
36: end
*19038
```

```
0: "3Ghz BACKGROUND AVEREGING PROGRAM":
1: "AVEREGES BACKGROUND DATA FOR USE IN FINAL COMPUTATIONS":
2: flt 2
3:
4: ent "FILE ASSOCIATED WITH",A
5: dim D[3,6,8,2];0→P;0→R;0→V;0→M;0→D;0→G
6: ent "IRRADIATION INT.,1-6;1=128 etc...",M
7: ent "VOLTAGE OUTPUT?,ENTER Vo",V
8: sfg 14
9: -116.32+4.98*ln(V)→R
10: ent "PAD SETTING?,ENTER PAD",D
11: R+D-30→P
12: tn^(P/10)→Q
13: (4π)^3*4.42^4→K
14: 15*19.85*.0013→Y
15: K/Y→C
16: if M=1;10000→X
17: if M=2;5000→X
18: if M=3;500→X
19: if M=4;50→X
20: if M=5;5→X
21: if M=6;.5→X
22: C*Q/X+S→S
23: G+1→G;0→T;ent "FINISHED??,ENT 1",T
24: if T#1;gto 7
25: if T=1;S/G→D[1,M,8,2];0→G;0→S
26: if M=6;gto "LIST"
27: if M#6;gto 6
28: "LIST":dsp "TO LIST ON PRINTER PRESS CONT."
29: stp
30: prt "FILE #",A;spc 2
31: for N=1 to 6
32: prt D[1,N,8,2];spc 3
33: next N
34: end
*12496
```

```
***********************************
*                                 *
*                                 *
*                                 *
*                                 *
*      DATA AVEREGING PROGRAM     *
*                                 *
*                                 *
*                                 *
*                                 *
***********************************
```

```
0: "AVEREGING PROGRAM INCORPORATING BACKGROUND CORRECTION":
1: "SUBTRACTS THE BACKGROUND AT EACH POINT AND PRINTS AVEREGED RESULTS":
2:
3: 0→V;0→W;0→X;0→Y
4: ent "WHICH DATA TAPE?, ENT 1 OR 2",W
5: ent "WHICH TRACK ON TAPE?",X
6: trk X
7: dim A$[15,80],B$[15,6],D[3,6,3,2],Q[3,6,8],C$[7,40]
8: ent "WHICH FREQUENCY ?",C$[7]
9: ent "WHICH FILE ??",Y
10: ldf Y,A$,B$,D[*],Q[*]
11:
12: 0→A;0→B;0→C;0→D;0→E;0→F;0→G;0→H;0→I;0→J;0→K;0→L;0→M;0→N;0→O;0→P
13: 0→R;0→S;0→T;0→U;0→Z;0→D[1,1,1,1];0→r0
14: for Z=1 to 6;0→D[1,Z,1,1];next Z
15: "INCIDENT POWER IS 128 W/sqM"→C$[1]
16: "INCIDENT POWEA IS 64 W/sqM"→C$[2]
17: "INCIDENT POWER IS 6.4 W/sqM"→C$[3]
18: "INCIDENT POWER IS .64 W/sqM"→C$[4]
19: "INCIDENT POWER IS .064 W/sqM"→C$[5]
20: "INCIDENT POWER IS .0064 W/sqM"→C$[6]
21: for Z=1 to 6
22: ent D[2,Z,1,1]
23: next Z
24: for Z=1 to 8
25: D[1,5,1,1]+Q[1,5,Z]+Q[2,5,Z]+Q[3,5,Z]→D[1,5,1,1]
26: D[1,6,1,1]+Q[1,6,Z]+Q[2,6,Z]+Q[3,6,Z]→D[1,6,1,1]
27: next Z
28: D[1,5,1,1]/24→D[1,5,1,1]
29: D[1,6,1,1]/24→D[1,6,1,1]
30: D[1,5,1,1]/D[2,5,1,1]→D[1,5,1,2]
31: D[1,6,1,1]/D[2,6,1,1]→D[1,6,1,2]
32: (D[1,5,1,2]+D[1,6,1,2])/2→D[3,3,3,2]
33: for Z=1 to 6
34: D[2,Z,1,1]*D[3,3,3,2]→D[3,Z,1,1]
35: next Z
36: 1→P
37:
38: for Z=1 to 8
39: Q[1,P,Z]-D[3,P,1,1]→r0;if r0<0;0→r0
40: A+r0→A
41: Q[2,P,Z]-D[3,P,1,1]→r0;if r0<0;0→r0
42: B+r0→B
43: Q[3,P,Z]-D[3,P,1,1]→r0;if r0<0;0→r0
44: C+r0→C
45: next Z
46: A/8→A
47: B/8→B
48: C/8→C
49:
50: "AVEREGE OVER CUTS":
*32525
```

```
51: for Z=1 to 3
52: Q[Z,P,1]-D[3,P,1,1]→r0;if r0<0;0→r0
53: D+r0→D
54: Q[Z,P,2]-D[3,P,1,1]→r0;if r0<0;0→r0
55: E+r0→E
56: Q[Z,P,3]-D[3,P,1,1]→r0;if r0<0;0→r0
57: F+r0→F
58: Q[Z,P,4]-D[3,P,1,1]→r0;if r0<0;0→r0
59: G+r0→G
60: Q[Z,P,5]-D[3,P,1,1]→r0;if r0<0;0→r0
61: H+r0→H
62: Q[Z,P,6]-D[3,P,1,1]→r0;if r0<0;0→r0
63: I+r0→I
64: Q[Z,P,7]-D[3,P,1,1]→r0;if r0<0;0→r0
65: J+r0→J
66: Q[Z,P,8]-D[3,P,1,1]→r0;if r0<0;0→r0
67: K+r0→K
68: next Z
69: D/3→D
70: E/3→E
71: F/3→F
72: G/3→G
73: H/3→H
74: I/3→I
75: J/3→J
76: K/3→K
77:
78: "AVEREGE OVER ALL MEASUREMENTS":
79: for Z=1 to 8
80: Q[1,P,Z]-D[3,P,1,1]→r0;if r0<0;0→r0
81: L+r0→L
82: Q[2,P,Z]-D[3,P,1,1]→r0;if r0<0;0→r0
83: L+r0→L
84: Q[3,P,Z]-D[3,P,1,1]→r0;if r0<0;0→r0
85: L+r0→L
86: next Z
87: L/24→L
88:
89: "OVER ALL STANDARD DEVIATION":
90: for Z=1 to 8
91: (Q[1,P,Z]-D[3,P,1,1]-L)^2+(Q[2,P,Z]-D[3,P,1,1]-L)^2→M
92: M+(Q[3,P,Z]-D[3,P,1,1]-L)^2→M
93: next Z
94: √(M/24)→M
95:
96: "PRINT STATEMENTS":
97: wrt 6,"FILE #",Y," ","ON TRAK #",X," ","OF TAPE #",W
98: wrt 6,A$[1]
99: wrt 6
100: wrt 6,C$[7]," AVEREGES CORRECTED FOR BACKGROUND"
*15042
```

```
101: wrt 6
102: if P=1;wrt 6,C$[1]
103: if P=2;wrt 6,C$[2]
104: if P=3;wrt 6,C$[3]
105: if P=4;wrt 6,C$[4]
106: if P=5;wrt 6,C$[5]
107: if P=6;wrt 6,C$[6]
108: wrt 6;wrt 6
109: fmt 1,4x,"X-Y",4x,e10.2,20x,"  0 deg",4x,e10.2
110: fmt 2,4x,"Y-Z",4x,e10.2,20x," 45 deg",4x,e10.2
111: fmt 3,4x,"Z-X",4x,e10.2,20x," 90 deg",4x,e10.2
112: fmt 4,4x,37x,"135 deg",4x,e10.2
113: fmt 5,4x,37x,"180 deg",4x,e10.2
114: fmt 6,4x,37x,"225 deg",4x,e10.2
115: fmt 7,4x,"AVG. OVERALL",4x,e10.2,11x,"270 deg",4x,e10.2
116: fmt 8,4x,"S.D. OVERALL",4x,e10.2,11x,"315 deg",4x,e10.2
117: wrt 6.1,A,D
118: wrt 6.2,B,E
119: wrt 6.3,C,F
120: wrt 6.4,G
121: wrt 6.5,H
122: wrt 6.6,I
123: wrt 6.7,L,J
124: wrt 6.8,M,K
125: wrt 6;wrt 6;wrt 6;wrt 6
126: P+1→P;if P<=6;gto 33
127: wrt 6;wrt 6;wrt 6;wrt 6;wrt 6
128: gto 9
129: "END":end
*30653
```

```
0: "DATA AVEREGING PROGRAM WITHOUT BACKGROUND CORRECTION":
1: "AVEREGES SIGNATURES FROM SECOND DATA TAPE w/o SUBTRACTING BACKGROUND":
2: 0→V;0→W;0→X;0→Y
3: ent "WHICH DATA TAPE?, ENT 1 OR 2",W
4: ent "WHICH TRACK ON TAPE?",X
5: trk X
6: dim A$[15,80],B$[15,6],D[3,6,8,2],Q[3,6,8],C$[7,40]
7: ent "WHICH FREQUENCY ??",C$[7]
8: ent "WHICH FILE ??",Y
9: ldf Y,A$,B$,D[*],Q[*]
10: 0→A;0→B;0→C;0→D;0→E;0→F;0→G;0→H;0→I;0→J;0→K;0→L;0→M;0→N;0→O;1→P;0→Q
11: 0→R;0→S;0→T;0→U;0→Z
12: "INCIDENT POWER IS 128 W/sqM"→C$[1]
13: "INCIDENT POWEA IS 64 W/sqM"→C$[2]
14: "INCIDENT POWER IS 6.4 W/sqM"→C$[3]
15: "INCIDENT POWER IS .64 W/sqM"→C$[4]
16: "INCIDENT POWER IS .064 W/sqM"→C$[5]
17: "INCIDENT POWER IS .0064 W/sqM"→C$[6]
18:
19:
20: "AVEREGE OVER ALL MEASUREMENTS":
21: for Z=1 to 8
22: L+Q[1,P,Z]+Q[2,P,Z]+Q[3,P,Z]→L
23: next Z
24: L/24→L
25:
26: "OVER ALL STANDARD DEVIATION":
27: for Z=1 to 8
28: (Q[1,P,Z]-L)^2+(Q[2,P,Z]-L)^2+(Q[3,P,Z]-L)^2→M
29: next Z
30: √(M/24)→M
31:
32: "PRINT STATEMENTS":
33: wrt 6,"FILE #",Y," ","ON TRAK #",X," ","OF TAPE #",W
34: wrt 6,A$[1]
35: wrt 6
36: wrt 6,C$[7]," AVEREGES WITHOUT BACKGROUND CORRECTION"
37: if P=1;wrt 6,C$[1]
38: if P=2;wrt 6,C$[2]
39: if P=3;wrt 6,C$[3]
40: if P=4;wrt 6,C$[4]
41: if P=5;wrt 6,C$[5]
42: if P=6;wrt 6,C$[6]
43: wrt 6;wrt 6
44: fmt 7,4x,"AVG. OVERALL",4x,e10.2
45: fmt 8,4x,"S.D. OVERALL",4x,e10.2
46: wrt 6.7,L
47: wrt 6.8,M
48: wrt 6;wrt 6;wrt 6;wrt 6
49: P+1→P;if P<=6;gto 20
50: wrt 6;wrt 6;wrt 6;wrt 6;wrt 6
51: 1→P
52: gto 8
53: "END":end
*10684
```